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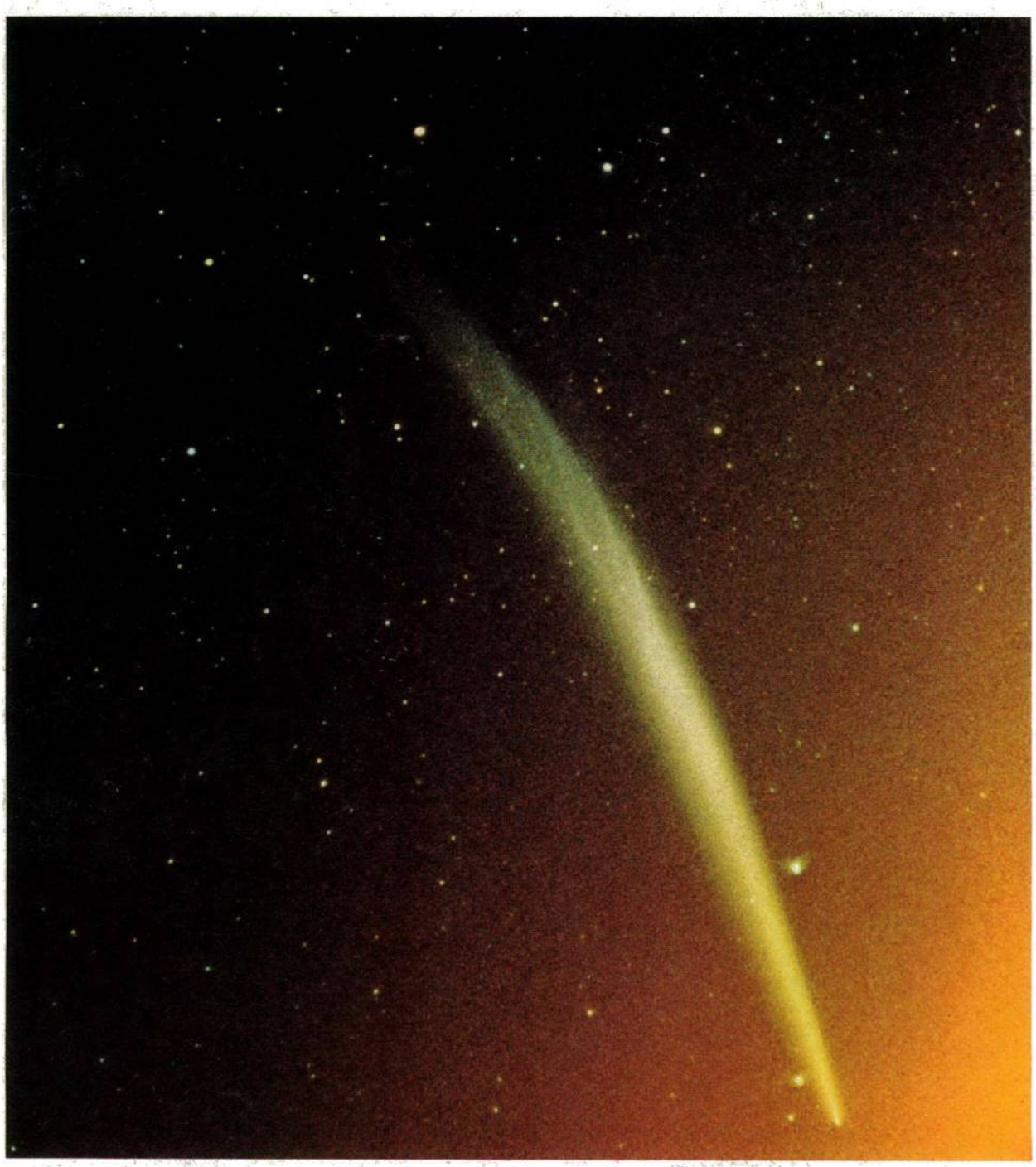

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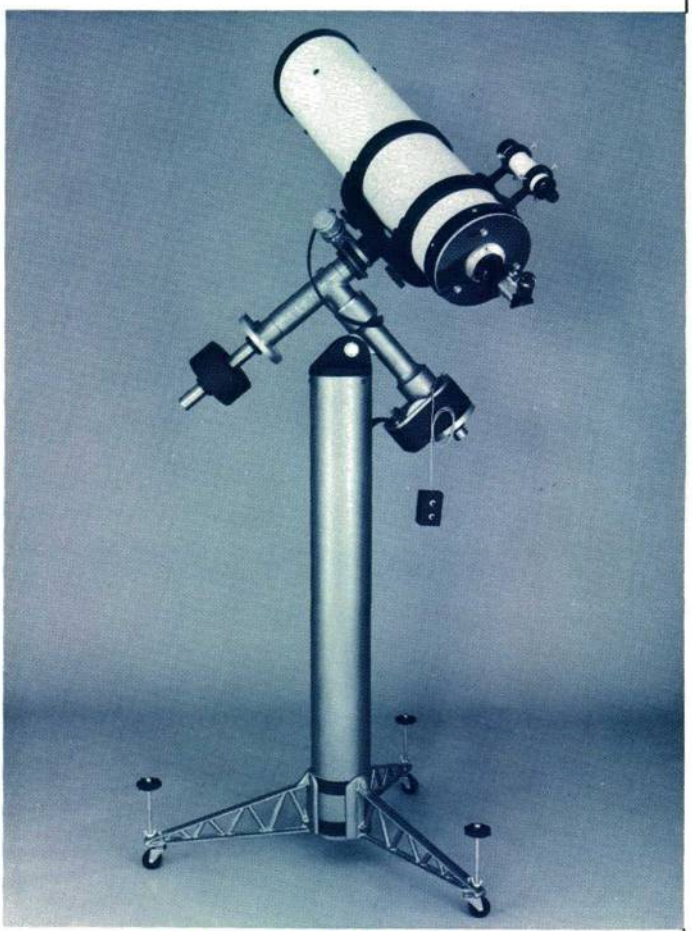

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This dramatic photograph of Comet Ikeya-Seki (1965f) was taken while the comet was in the morning sky just before it reached perihelion with the sun. Here, the comet's gossamer tail is projected into a star studded night sky while the head touches the first rays of the rising sun.

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Birth and Death of a Comet

by
F. L. Whipple

At rare intervals a frozen lump of primordial cosmos invades our part of the solar system. From our vantage point on planet Earth we watch these celestial interlopers — the comets — as they gracefully fling their gossamer tails across millions of miles of interplanetary space. A large comet, like Kohoutek, is a rare and marvelous spectacle — an awesome glimpse of an object as alien as anything seen in earthly skies. What are the comets? Where do they come from?

To study a comet in its nursery and its deathbed, we need first to learn about the comet in its prime of life. A comet at its prime usually terrifies people; at least it did before astronomy became a science. Even as recently as May 18, 1910, the following appeared in the New York **Times**:

> **"Chicago, May 17 — Terror occasioned by the near approach of Halley's comet has seized hold of a large part of the population of Chicago. Especially has the feminine portion succumbed. All else is forgotten. Comets and their ways and habits have been the principal topic discussed in the streets, cars and elevated trains today ...."**

The sale of "comet pills" was apparently a temporary financial success. Comets that stretch their fiery-looking tails across the sky at rare intervals are not to be taken lightly. Typically, they wander capriciously among the stars for a few days or months before they fade away, "harbingers of the death of kings". The Chinese took comets so seriously that they kept careful records for more than 2000 years. Ho Peng Yoke catalogs 581 comets from Chinese sources up to 1600 A.D., a number of these being confused in the records with novae or new stars and with meteor falls or shooting stars.

People long accepted comets as atmospheric phenomena involving poisonous vapors, and unjustly accused them of either starting or foretelling wars, pestilences, and other unhappy events for man. Only rarely were comets accepted as good omens, as in the famous case of Halley's comet on the Bayeau tapestry commemorating the battle of Hastings in 1066. Apparently the comet cheered the Normans, frightened the Saxons, and possibly influenced the success of William the Conqueror.

No progress was made in understanding the true nature of comets until Tycho Brahe, in Denmark, with his newly developed equipment, gunsighted the bright comet of 1577, proving that it moved in a region of space farther away than

When Comet Kohoutek was out beyond the orbit of Pluto nearly a decade ago, it was a 15 mile wide ball of ice floating silently, but with gathering momentum toward its rendezvous with the sun. The sun, appearing like a brilliant star, was still too distant to begin to melt the outer layers of this colossal cosmic iceburg. The comet was not discovered until it was within the orbit of Jupiter in early 1973.

Original Painting for ASTRONOMY by Victor Costanzo

COSTANZO

the moon. Tycho's results definitely relieved comets from the accusation of being atmosphere polluters, but they were still thought to be ominous celestial visitors with possibly malicious intent, capable of producing dire effects on humans. But by that time, however, Nicolaus Copernicus was already lighting the dawn of modern astronomy. Last year we celebrated his 500th birthday and with it his revolutionary idea that the planets revolve about the sun. Following Copernicus' lead, Sir Isaac Newton formulated his universal law of gravitation, concluding that comets should obey the same laws as do the planets. Because comets come and go without warning, Newton suspected that they might be moving in open parabolic orbits about the sun. On this assumption, he developed complicated geometrical methods for calculating their orbits. But it took Edmund Halley, an ardent disciple of Newton, to put his own scientific reputation "on the line" by actually predicting the return of a comet. He concluded that the bright comets of 1531, 1607, and 1682 were not moving in parabolic or hyperbolic open-ended orbits but in extremely elongated ellipses that he calculated to be identical within the errors of measurement. So, subject to considerable scorn by skeptical colleagues, he predicted that this comet would return in 1758, 102 years after his own birth. Everyone now knows that this great comet bearing Halley's name has a period of 76 to 77 years, and it not only returned in 1758 on schedule but also in 1835 and 1910, as mentioned earlier. We await a return in 1986. Very likely the Chinese observed it in 467 B.C. or before, and quite certainly in 239 B.C.

The telescope and Newton's laws have now told us a lot about the motions of comets. Most of them move in extremely elongated orbits, as Newton expected, but the orbits are closed about the sun, some with periods of millions of years. Comets are true members of the solar family. None has certainly come from infinity in hyperbolic orbits, although quite a few are disturbed by the gravitational attraction of the planets, particularly Jupiter and Saturn, so that they will never return, drifting forever through the far reaches of our galaxy. In 1950, Dutch astronomer Jan Oort showed that the sun's family includes perhaps 100 billion comets in a great cloud extending out some 50,000 times the distance from Earth to the sun. Stars occasionally pass through this cloud like bullets through a cloud of gnats, knocking out some of them and sending a few close to the sun for us to observe. But the cloud, with losses, can persist for the age of the solar system (4.6 billion years, as first shown by E. Opik in 1931).

Of some 600 individual comets so far observed, about 100 move in orbits with periods less than 200 years. These comets have been disturbed by Jupiter and Saturn so that instead of moving in very elongated paths they now have much smaller orbits. E. Everhart of Denver, Col. has recently shown how repeated fairly close approaches to these planets over hundreds or thousands of periods can randomly reduce the orbit sizes and periods. But many comets are lost in the process, mostly to infinity. All those with periods less than 30 years move in the same "forward" sense as the planets about the sun, with orbits only moderately inclined to that of Earth. Only those originally moving in this direction near the plane of the planets have a chance to become short-period comets. The very long-period comets move in randomly distributed planes.

The mystery of comets was intensified by Johann Franz Encke in 1819, when he studied the orbit of the shortest period comet, discovered in 1786. This comet defied Newton's law of gravitation. It persisted in returning successively 2-1/2 days earlier than predicted in its 3.3 year period. In honor of Encke's first finding its period and then its mysterious motion, the comet now carries his name. Currently, the period change has diminished to about 10 percent of its earlier value.

The strange motion of Encke's comet might have been explained by a resisting medium in space that forces the comet into a smaller orbit with a shorter period on successive revolutions. But this theory fails because some comets move in short-period orbits with increasing periods. Brian Marsden of the Smithsonian Astrophysical Observatory recently showed that all but two of some 20 short-period comets deviate from Newton's law, while half of their periods are increasing. No one has dared to propose an interplanetary medium that would push a comet forward in its orbit.

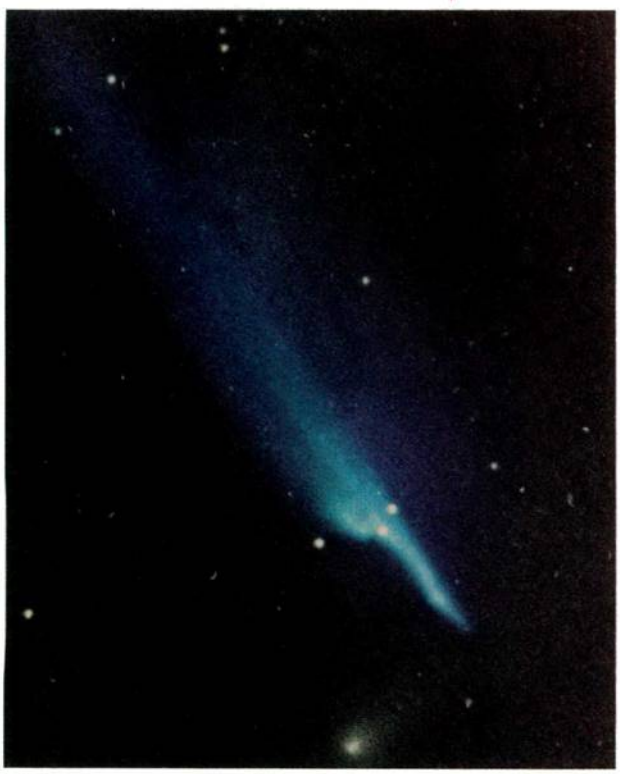
The mystery of comets was further intensified by the invention of the spectrograph, a device containing a prism or diffraction grating which spreads the light of a star or comet into its complete expanded spectrum of colors. Lines of color from atoms or bands of color from mole-

The 1969 Comet Tago-Sato-Kosaka dramatically shows an ion tail — one of two tail types seen in comets. These tails, consisting only of molecules that have lost an electron and carry a plus charge stream out and away from the sun, curving gently and gracefully backward from the motion of the comet out to as much as 100 million kilometers.

1969 Soviet Expedition to Chile Photograph

cules identify the radiating atoms or molecules in the source. Strange broken molecules are found in the comet heads — molecules that are completely unstable in earthly laboratories. Furthermore comets show two kinds of tails. One consists only of ionized molecules — molecules that have lost an electron, thus carrying a plus charge. These **ion tails** stream out from the sun, curving gently and gracefully backward from the motion of the comet out to as much as a hundred million miles. On the other hand, many comets show tails that curve sharply backward. These tails consist of dust, as demonstrated by their reddish color and the way in which they scatter sunlight. Powdery dust is blown away from a comet's head by the pressure of sunlight, but the ion tails long remained a mystery because they show spurts and motions in the anti-sun direction corresponding sometimes to more than 100 times the acceleration of the solar gravity. Sunlight alone cannot exert such great pressure on the ions in comets' tails. Some other type of force is needed.

Not only do comets spew off dust and gas but they produce great meteor streams in space — consisting of sandgrain to pea-sized bodies that move along the comet orbits. When Earth happens to pass close to an orbit a meteor "shower" results. It is thought that all the known meteor showers are due to comet debris. Those bright comets that come near the sun also show the spectra of the earthy meteoric materials such as sodium, chromium, iron, or nickel. These atoms are freed in the atmospheres of comets, under sufficiently intense solar radiation, to produce their characteristic spectral lines.



Photograph by Orien A. Ernest

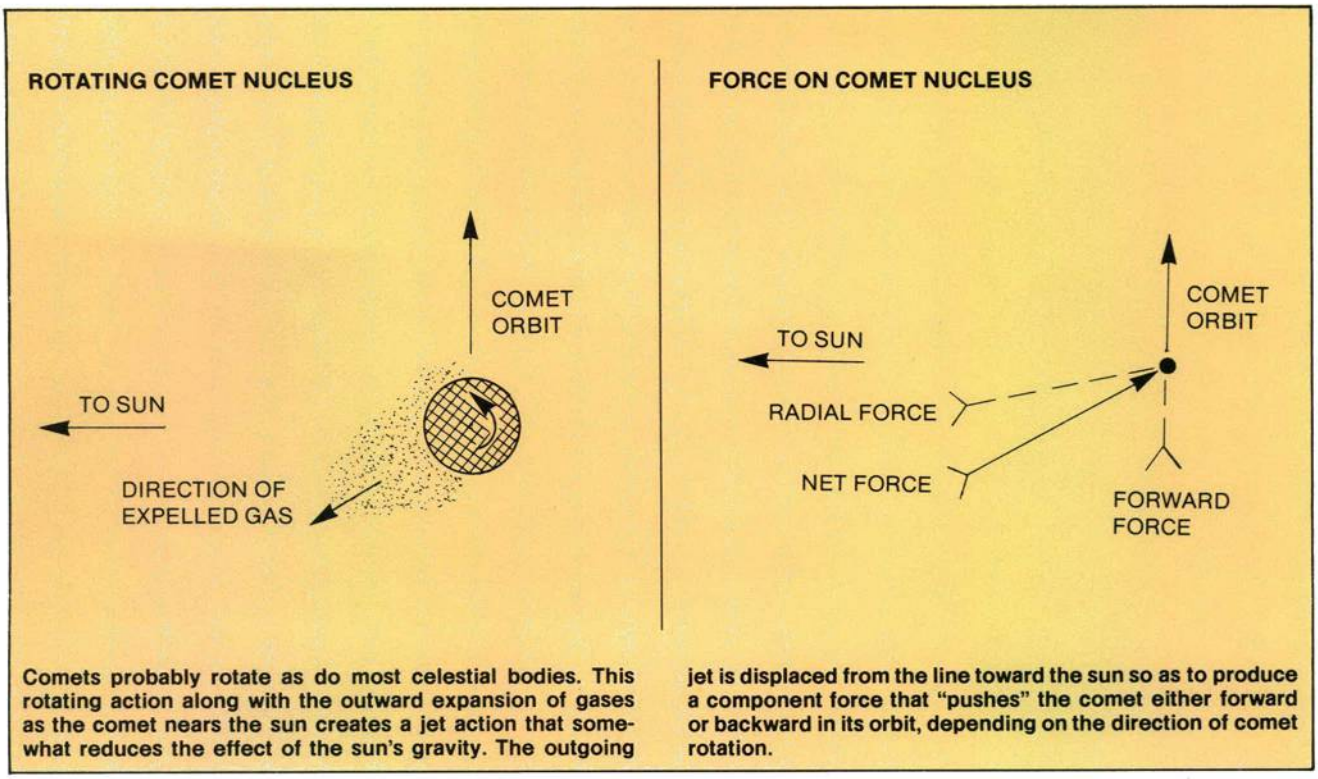
With his cooled emulsion camera and High Speed Ektachrome film, Orien A. Ernest captured two "rare" astronomical phenomena. At center he captured a meteor during a five minute exposure of Comet Kohoutek (fuzzy star near the bottom of the photograph).

Some comets have been known to brighten erratically as they approach the sun. In just a few days Comet Tuttle-Giacobini-Kresak dramatically flared to 10,000 times its predicted brightness in late May and early July, 1973. Then, in an equally short time it dropped back to normal. Generally the head, or coma, of a comet shrinks as it approaches the sun in the inner solar system.

What sort of bodies are these comets — changing in brightness and size so strangely, disobeying gravitational laws, sending out broken molecules instead of stable ones, ejecting dust and meteoritic particles and persisting in this loss of substance for tens or hundreds of revolutions about the sun in small orbits?

The "gravel bank" model of a comet was proposed to answer these questions. In this concept, the nucleus consists of a large diffuse mass of gravel and finer particles in which gases have been absorbed. The finer the particles are, the larger the total surface is for a given total mass of material. An approach to the sun heats the gravel and drives off the gases. Among the various problems with this solution is the fact that solids can absorb only a certain amount of gas, and that most of it is removed at the first heating by sunlight in a vacuum. By the 1940s, it had become abundantly clear that there is no immediate source of gas between the planets to replenish the gas that the sun would remove from particles in orbit. Also, there is not enough material between the planets to produce a resisting medium and certainly no mechanism for an accelerating medium.

These and other problems of comets are solved if the nucleus of a comet is simply a ball of ice or snow, with embedded solid particles (the "dirty snowball" model proposed by the author in 1950). The ice need not be water ice alone but can include methane, ammonia, carbon monoxide, and other more complex ices that would be vaporized near the sun to produce the comet activity. If this ball of dirty ice is a mile or more in diameter it can withstand many close approaches to the sun before its substance vaporizes away. Small earthy dust particles, some of them stuck together in larger aggregates, can account for the dust tails



Comets probably rotate as do most celestial bodies. This rotating action along with the outward expansion of gases as the comet nears the sun creates a jet action that somewhat reduces the effect of the sun's gravity. The outgoing jet is displaced from the line toward the sun so as to produce a component force that "pushes" the comet either forward or backward in its orbit, depending on the direction of comet rotation.

and the meteor streams. As sunlight vaporizes or sublimates the ices to gas, the escaping gas carries off the dust particles to produce the general activity of a comet.

But the key to the power of the icy comet model lies in the ejection of material on the sunlit side. The outgoing gases produce a jet action on the nucleus, a force away from the sun, effectively reducing the solar gravity by a small amount. But now suppose that the comet nucleus is rotating (and we know of no celestial body that isn't). If so, the direction of the jet is displaced from the line toward the sun producing a component of force that can push the comet either forward or backward in its orbit, depending on the sense of rotation. Would such forces be large enough to produce measurable effects on the orbits of sizable bodies? Calculations show that indeed this can be true if the necessary ices are actually present and are vaporized by sunlight as the model suggests. But the quantity of gases ejected by a comet needed to be considerably larger than the amount measured by the actual spectra available in 1950. This led to the suspicion that ordinary water might be the major source of ice and that we simply could not observe the large amount of hydrogen that would be released when the solar radiation dissociated the water molecule into hydrogen and oxygen. Ludwig Biermann showed that a huge cloud of hydrogen must exist about an icy comet if only we could observe it in the very far ultra-violet, where our atmosphere is opaque.

The space age provided the proof! In 1970, Arthur D. Code and Charles F. Lillie employed NASA's Orbiting Astronomical Observatory (OAO 2) — freed from the curse of Earth's atmosphere — to detect a huge cloud of hydrogen radiating in the very far ultraviolet around two large comets, Tago-Sato-Kosaka (1969 IX) and Bennett (1970 II). J. Berteaux and J. Blamont immediately confirmed their result for Comet Bennett by means of the Orbiting Geophysical Observatory (OGO 5). The hydrogen cloud stretched for much more than a million miles away from the sun and about that far in the sunward direction. Code and Lillie found that some tens of tons per second of water must have been liberated to provide the cloud, or some hundred million tons during the passage of Comet Bennett about the sun. To provide such huge quantities of water on each solar passage and still to persist for many revolutions, the nucleus of a large comet must be several miles in radius.

Water ice alone, however, cannot account for comet activity very far from the sun. At the huge distance of 5.2 times the earth-sun distance, where Comet Kohoutek was recently discovered, water ice in the faint sunlight would be almost completely inactive because the temperature is too low. More volatile substances are required. Pol Swings and Armand Delsemme of Belgium provided an answer. The water ice must really be in the form of fine snow, with highly volatile parent mole-

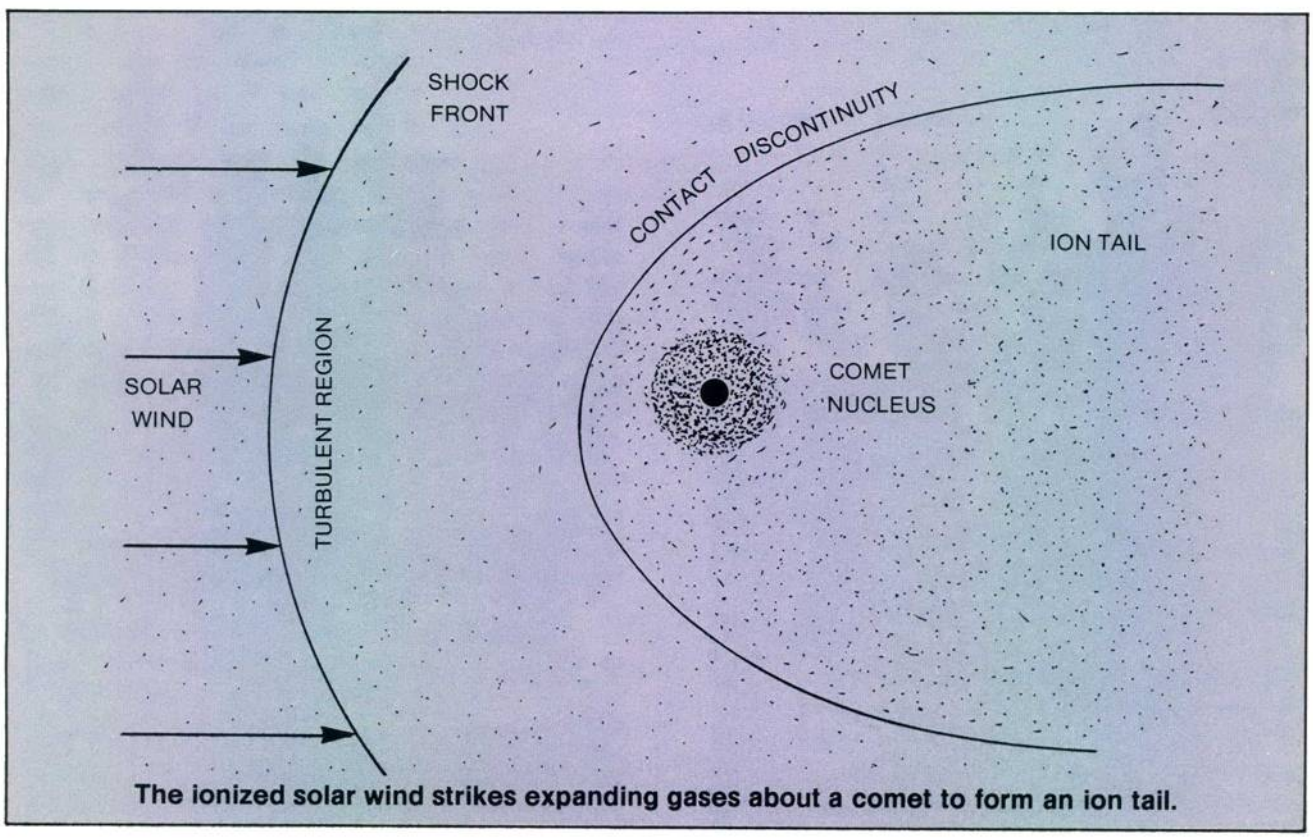
Hale Observatories Photograph

Comet Mrkos, one of the brightest comets of this century, was visible to the naked eye for a short time in the late summer of 1957. The photograph above shows both the comet's dust tail and gas tail. The dust tail is the faint curved nebulosity below the long streaked more apparent gas tail. This faint tail can be understood easily as fine dust blown away from a comet's head by the pressure of sunlight. (It is the dust tail, however, that is visible to the naked eye.)

cules trapped in the lacy flakes. At great solar distances out to Jupiter, the sunlight vaporizes the parent molecules. They in turn break the delicate snow crystals and blow them away along with very fine dust. Even though this theory must be true in principle we still have to identify the parent molecules by observation from space if we are to be certain about the true nature of comets. Space missions to comets are urgently needed and are now being seriously planned by NASA.

The space program has already solved another comet mystery, at least in principle. What physical processes produce the great ion tails streaming away from bright comets? What forces ionize the comet molecules and then force them back with velocities of many miles per second? The solution to these problems, oddly enough, was first suggested by a combination of solar and geophysical research. Long ago a correlation was discovered between solar activity such as sunspots and solar flares and terrestrial events such as the aurora borealis (northern lights), radio disturbances, and magnetic disturbances. Earth events lag the solar by a number of hours, indicative of high velocity particles shot out from the sun and striking Earth's upper atmosphere or ionosphere. Satellite laboratories outside Earth's atmosphere detected and determined the source of these events as "solar wind." The sun loses about a million tons per second of its million degree outer corona, blowing out at a speed of some 250 miles per second and carrying ionized gas with trapped magnetic fields deep into space far beyond Earth. As this solar wind strikes the expanding atmosphere of a comet, it ionizes some of the molecules by high energy electron impacts. The entangled magnetic fields carry these ions backward in the tail much like a magnetic fishnet that enfolds charged particles but lets the neutral ones flow through.

Today, most of the mystery of comets, if not the glamour, is dispelled now that we have learned about their general nature and the kinds of physical processes that occur in them. Nevertheless, a great comet can produce a spectacular celestial display. Before discussing the birth of a comet, we can still gain some insight by studying comet geriatrics. On the basis of the icy comet model, we can see not only why comets die but why they live so long. Actually the death of comets, as Mark Twain once said of himself, "has been greatly exaggerated". Comet Encke has been spewing out meteoritic material for at least a thousand revolutions about the sun, as evidenced by meteor orbits. Even though it may have faded in brightness a few times since its discovery in 1786, Comet Encke doesn't seem ready yet to "give up the ghost". Halley's comet has remained spectacular after more than 30 returns. On the other hand, Biela's comet really



The ionized solar wind strikes expanding gases about a comet to form an ion tail.

seems to have died — but with a real flare — splitting into two pieces while being observed in 1846, after 10 returns since its discovery in 1772. The comet, as twins, returned in 1852 after its normal 6.6 year period, but could be observed for only a month, whereupon both components disappeared and never have been seen since. However when Earth comes close to the orbit in early November, we see meteors, spectacular showers in 1798, 1933, and 1946. The "bones" of Biela's comet still float through space.

Holmes' comet, on the other hand, seems to have risen from the dead! When discovered by Holmes in 1892, it was a naked eye object but faded very rapidly. On its return, 6.9 years later in 1899 and again in 1906, it was barely visible in the largest telescopes. Afterward, Holmes' comet was generally pronounced dead because it could not be rediscovered on subsequent returns. Nevertheless, in 1964 Elizabeth Roemer, now at the Lunar and Planetary Laboratory in Tucson, Ariz. found it with the 40 inch reflector of the Naval Observatory at Flagstaff with only a 0.7 day correction to a prediction by Brian Marsden. It had faded by perhaps a million times from its maximum observed brightness!

Several comets have been seen to split, particularly the sun-grazing comets such as the spectacular Ikeya-Seki (1965 VIII), but usually one component, sometimes the brighter one, fades away rather rapidly. The best explanation for this strange behavior follows naturally from the icy model of the nucleus. A piece actually breaks off! The newly exposed area of one broken piece will equal that of the other. So, if highly volatile ices or molecules are thus exposed, both pieces will be equally active for a while, but the smaller one may soon disintegrate, perhaps completely. The gigantic tidal forces close to the sun can be expected to break up the nuclei of sun-grazing comets, and usually do. But some comets have split up in deep space far from the sun. Possibly, irregularly shaped comet nuclei "spin up" as they eject gas, finally to break apart by the centrifugal force of too rapid rotation. Possibly they collide with tiny asteroids. Or some comets coming in from the "deep freeze" of space may break by the heat of sunlight that expands and cracks the outer shell, like glass in boiling water.

But frankly, we cannot yet hold the pulse of an old comet to see whether it has really died. Indeed, we may question whether certain types of comets will really die at all, or like old soldiers, simply fade away. They may change into inactive small bodies superficially indistinguishable from the asteroids that are so numerous between Mars

These five photographs never before published show the effect of increased photographic exposure to bring out detail in a comet. This series shows Comet Bennett which appeared in 1970. At left, detail at the very heart of the comet's nucleus is visible. As photographic exposure was increased, more detail in the comet's coma was recorded. Compare the photograph at far right with the schematic drawing on page 11. An unofficial interpretation of the pinwheel effect is rotation of Comet Bennett's nucleus. While evidence was not conclusive, Lunar & Planetary Laboratory scientists believe this comet rotates once in 1.4 Earth days. Additional proof on comet rotation may be provided by Comet Kohoutek. See article text for additional details.

Lunar & Planetary Laboratory Photographs

and Jupiter. In fact, we distinguish asteroids from faint comets only by the fact that comets show a halo or coma that appears fuzzy in a telescope, whereas asteroids, except for the largest, are always completely starlike, bright points of light in the greatest telescopes. Thus the intriguing question arises as to whether some or most of the comets we observe will eventually change from "butterflies of the sky" into "grubby" asteroids. Is it possible that many of the "Apollo" group of asteroids that cross Earth's orbit are decrepit old comet nuclei, inactive since their ices and gases became exhausted, quiescent bodies still in orbit about the sun? They may provide some of the meteorites that we pick up on Earth. If we knew more precisely just how comets die, we could reconstruct their birth and growth with much greater confidence.

How is a comet born? How do we go about making a large ball of dirty ices? First we need a concentration of cold gas and dust in space. Our problem is to condense and collect this concentration into mile-wide masses. Where in the universe does one look for such relatively high density cold material? Interstellar space is not favorable in general, even near the place of our galaxy. Average space contains less than one hydrogen atom per cubic centimeter, and a thousandth as many earthy atoms. The collapse of a cloud of such gas, however, can provide the situation we need.

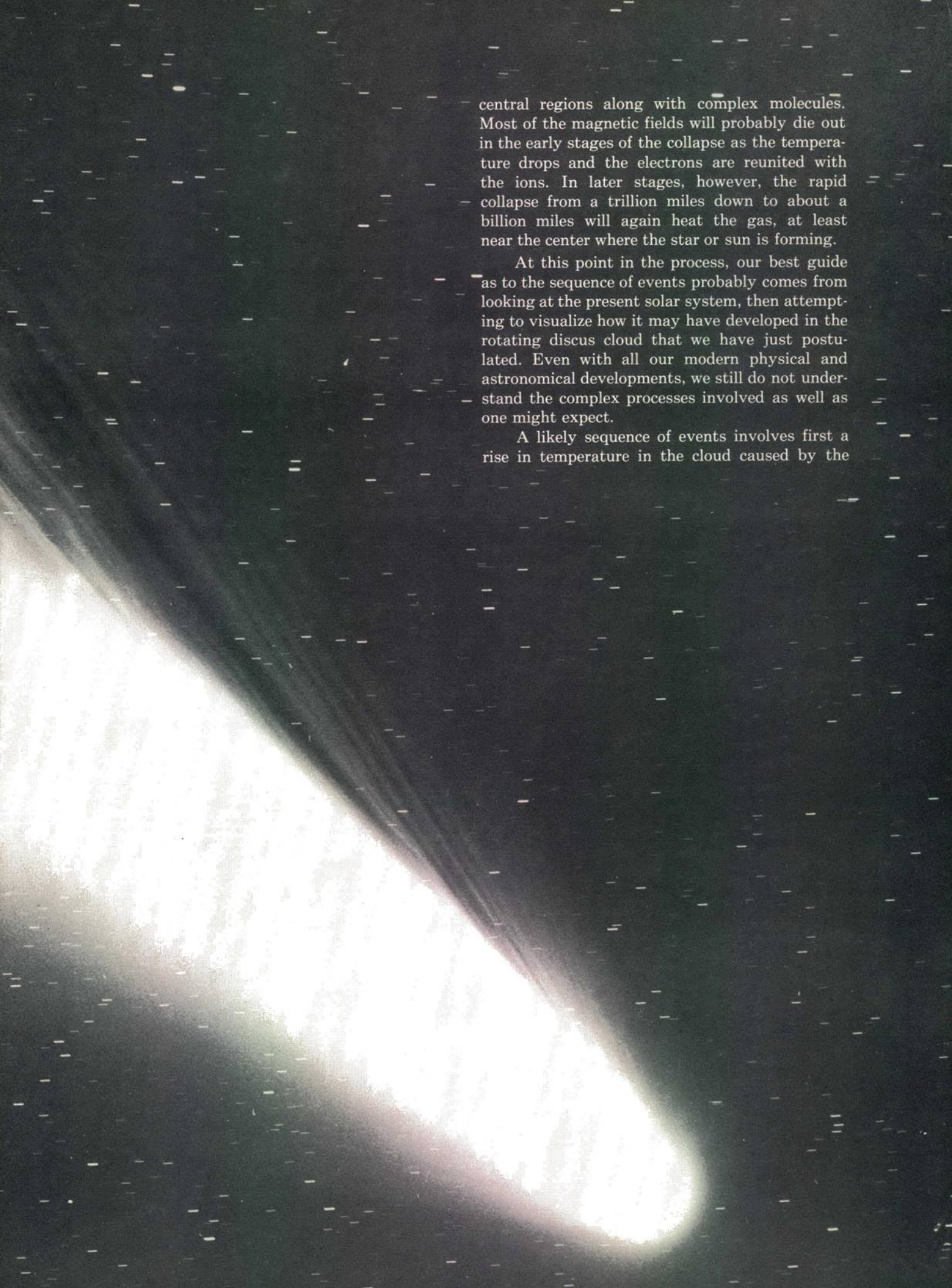
Photographs near the plane of our Milky Way show many regions where dark zones of high dust concentration obscure and scatter the light from more distant stars. Many of these regions show glowing clouds of bright emission lines produced by excitation of the radiation from hot stars in local regions. The Great Nebula in Orion is one of these. Such regions contain many new stars, generally hot massive stars much brighter than our sun. The existence of such "stellar nurseries" gives us confidence that smaller stars are also born there and that our solar system probably developed in some such region 4.6 billion years ago.

A great gas and dust cloud will always have some turbulent internal motion and rotation, so that on collapsing it will break up into several or many condensations from which stars or solar systems can form. The theory of such collapse, and particularly the final stages of star formation, is still too difficult for a thorough analysis. Even so, we can be confident that rotation will be frequent and probably universal in such condensations. Thus, most will end up as double stars, but some can develop into contracting disks rotating around a growing central mass. In the case of the solar system, we visualize this central mass as the sun and the outer rotating discus as the region in which the planets, asteroids, and comets were formed.

The known presence of weak magnetic fields in space complicates the theory of the collapse of the great clouds because the fields are carried by electrons in the partially ionized gas. The cloud will first cool with moderate collapse so that interstellar dust grains will condense in the

Comet Bennett was an extremely dusty comet, and this photograph not only shows long streaks of ion tail but also the massive dust tail. Photographs like this create the illusion that comets are swiftly moving fiery objects. In reality, they are quite cold and move slowly through the night sky.

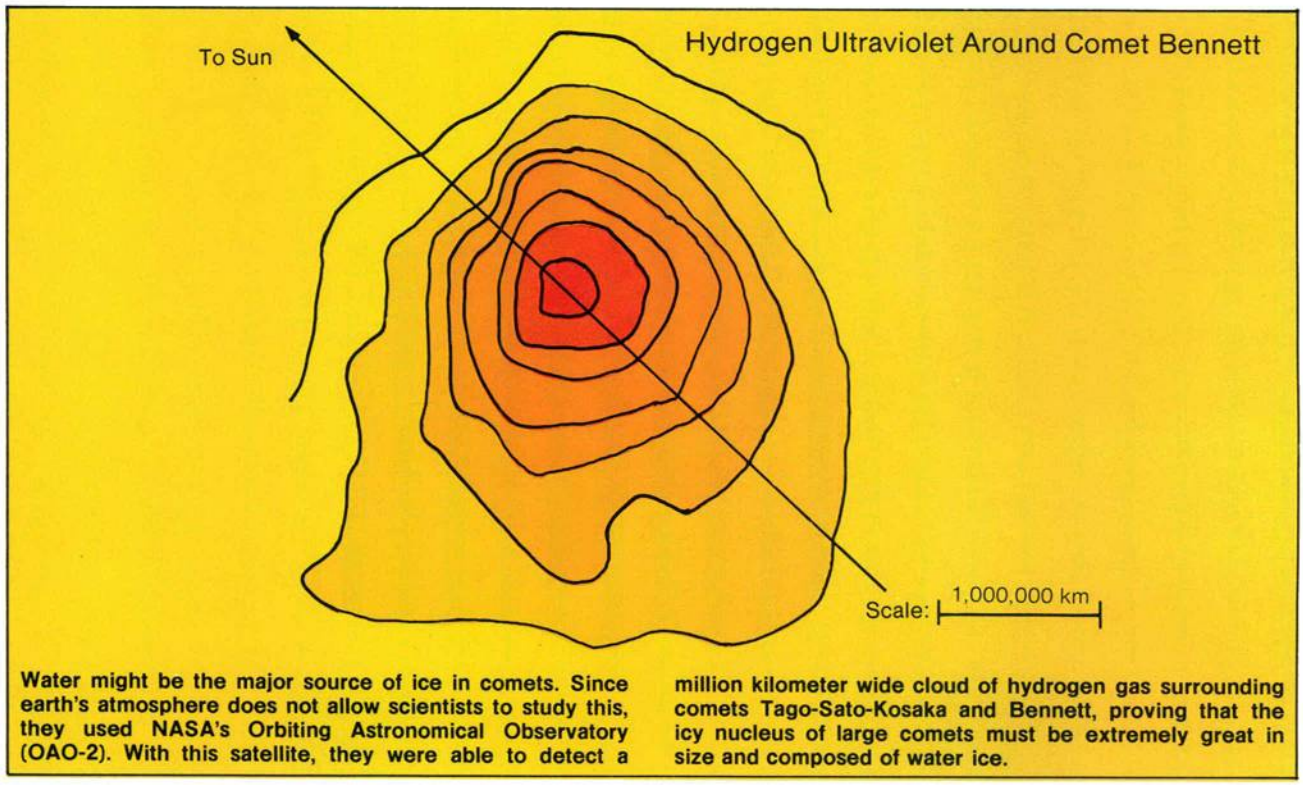
1970 Soviet Expedition to Chile Photograph



central regions along with complex molecules. Most of the magnetic fields will probably die out in the early stages of the collapse as the temperature drops and the electrons are reunited with the ions. In later stages, however, the rapid collapse from a trillion miles down to about a billion miles will again heat the gas, at least near the center where the star or sun is forming.

At this point in the process, our best guide as to the sequence of events probably comes from looking at the present solar system, then attempting to visualize how it may have developed in the rotating discus cloud that we have just postulated. Even with all our modern physical and astronomical developments, we still do not understand the complex processes involved as well as one might expect.

A likely sequence of events involves first a rise in temperature in the cloud caused by the



Water might be the major source of ice in comets. Since earth's atmosphere does not allow scientists to study this, they used NASA's Orbiting Astronomical Observatory (OAO-2). With this satellite, they were able to detect a million kilometer wide cloud of hydrogen gas surrounding comets Tago-Sato-Kosaka and Bennett, proving that the icy nucleus of large comets must be extremely great in size and composed of water ice.

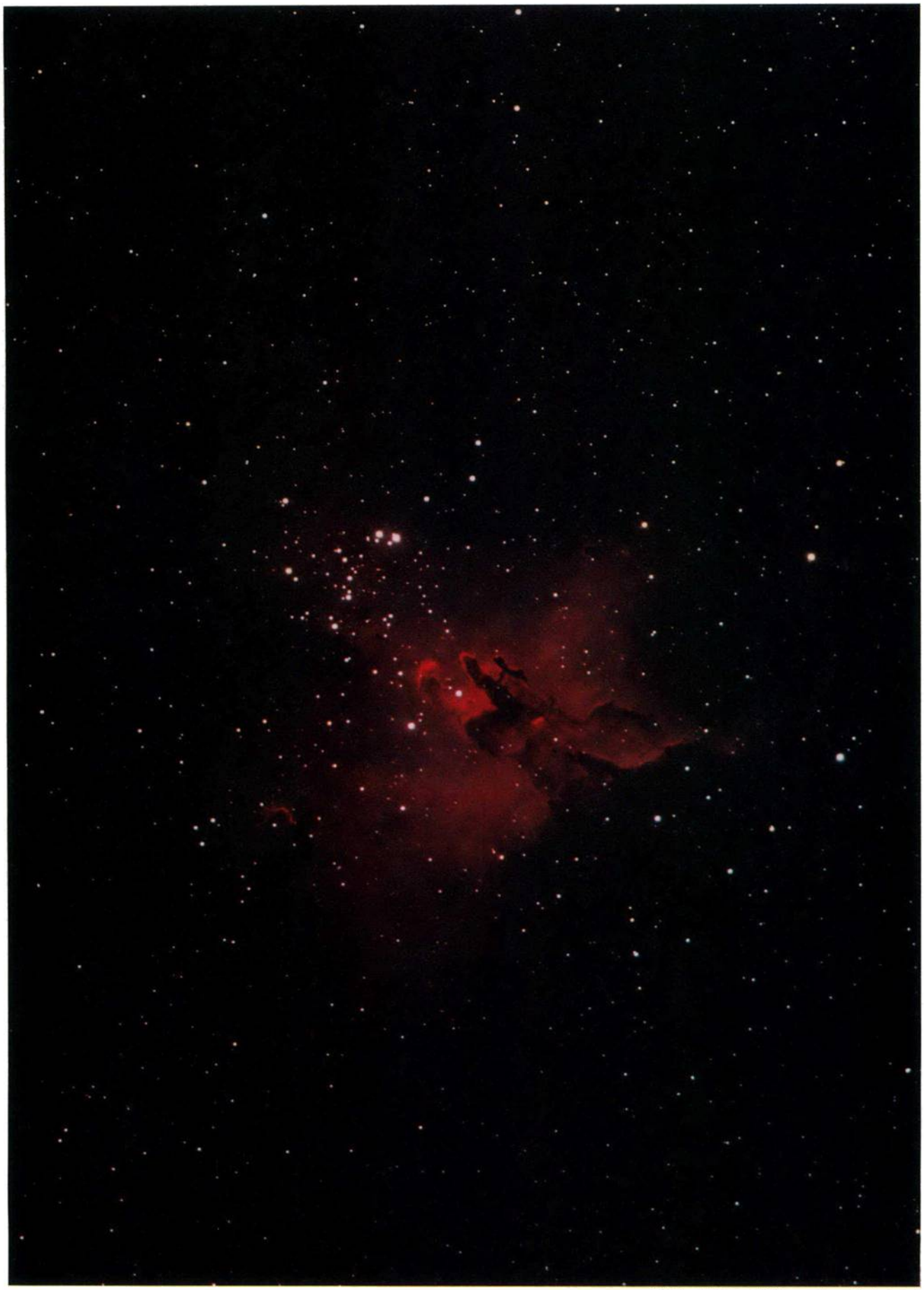
collapse. The temperature then falls by radiation allowing the condensation of dust grains at higher densities near the plane of the forming discus. These dust grains tend to fall toward the plane of the discus and also to aggregate by encounter with each other to form larger and larger bodies. The accumulation takes place rather rapidly (thousands or millions of years?) if the system is very quiescent except for general rotation. In the inner zones of the present terrestrial planets, the temperature must remain sufficiently high (more or less room temperature) so that water ice cannot condense. Thus Earth and other terrestrial planets inside Jupiter's orbit can accumulate only the earthy elements and their compounds, a fraction of a percent of the total mass in this part of the discus. Beyond Jupiter or perhaps Saturn, it is quite evident that the temperatures must be lower. In a solar mixture of gas, only some two percent of the total mass can form ices if the temperature falls sufficiently, say to a few tens of degrees above absolute zero. Superficially, the densities of Uranus and Neptune suggest that these planets could have been made almost entirely from ices. An interesting thought is that Uranus and Neptune are actually made out of comets. Pluto may be the largest solid comet still extant. At its huge solar distance, it will remain forever deep frozen and inactive.

Jupiter's composition, still poorly known, appears to be something like that of the sun, predominantly hydrogen and helium with a few or several percent of ices and earthy material added. It is almost as large as a similar mass of pure cold hydrogen. Were it much more massive, it would collapse at the center and be smaller in diameter. Saturn appears to be similar to Jupiter, but with a greater fraction of added ices and earthy stuff. Both must have accumulated primarily from the nebular gas.

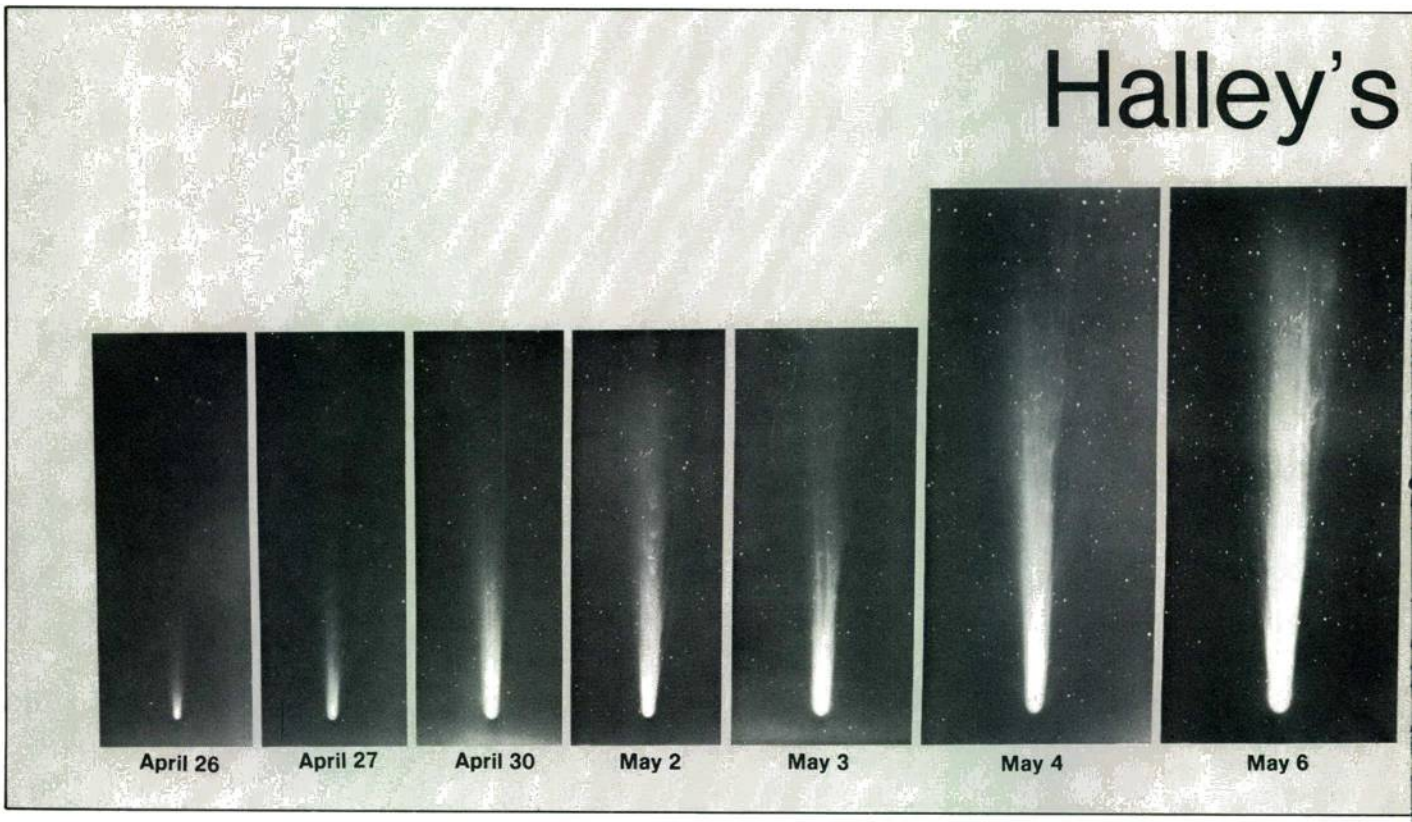
Three major problems (and a host of minor ones) must be solved if we are to accept as definitive this theory of the formation of comets and the solar system. We must somehow get rid of the leftover gas — some 98 percent of the total mass, mostly hydrogen and helium. It cannot freeze and collect on the terrestrial planets, asteroids, Uranus, Neptune, Pluto, or the comets. Also, we must slow down the sun's rotation from a period of perhaps 10 hours to nearly a month. Having solved these two major problems, we must somehow move the comets out from the region between Saturn and Pluto to the great Oort cloud, perhaps a thousand times greater in solar distance.

Fortunately the space age and modern stellar astronomy give us a clue as the probable solu-

Large clouds of gas, as in the recent photograph at right, are nurseries for new stars. These great gas and dust clouds have turbulent internal motion so that as they collapse they form stars and possibly solar systems. Smaller clouds coalesce around a central star and later become planets, planetoids and possibly comets.



Kitt Peak National Observatory Photograph

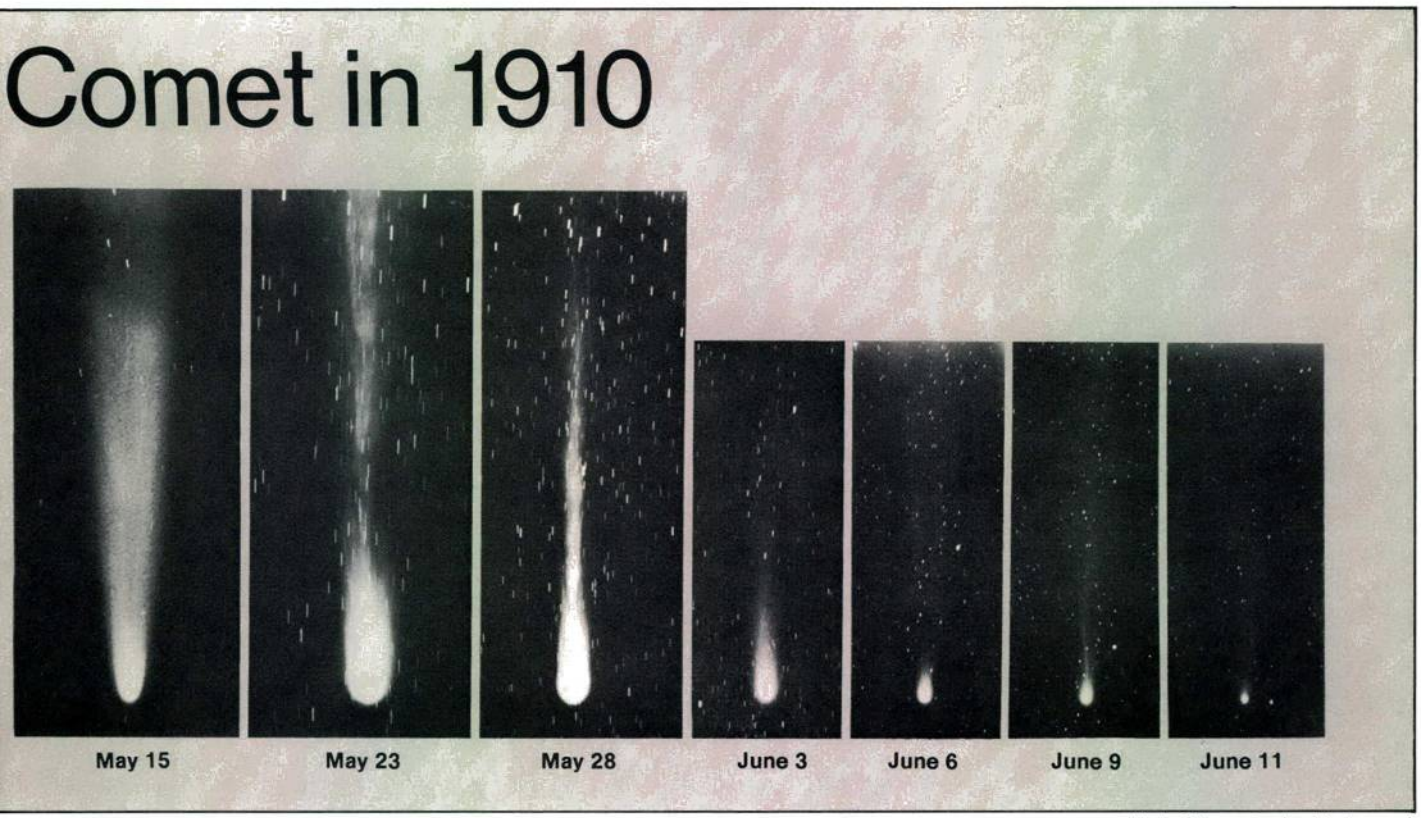


tion of the first two problems — a common solution, amazingly enough. The solar wind that produces the great ion tails of comets also carries with it magnetic fields that rotate with the sun, nearly like a solid body. They carry away some of the solar rotation, or angular momentum, albeit at a very slow rate today. Stellar astronomy tells us that some new stars, the T-Tauri stars, are ejecting mass at perhaps millions of times the rate the sun currently ejects the solar wind. If the primitive solar gale carries proportionately great angular momentum in rotating magnetic fields, it can both slow down the rotation of the young sun and, at the same time, blow the gas away from the discus containing the planets and the comets. Admittedly, no comprehensive theories for these complex processes have yet appeared, but general progress in theory and observation gives us confidence that an early solar gale can provide a solution to our two major problems.

Now we must face the problem of moving the comets out to the huge comet cloud. The only sizable force to do this is planetary attraction. Uranus and Neptune cannot swallow up all the comets near them in space. They can disturb a fraction of the comets into orbits elongated toward the inner solar system and out to great solar distances. Many are captured by the planets and the sun, particularly by Jupiter and Saturn. Many dissipate in the inner solar system when heated by the sun, as comets do today. Many are thrown to infinity, lost forever by the solar system. A small fraction of the original number, perhaps one percent or less, end in very elongated orbits. Öpik long ago showed that passing stars will systematically increase the minimum solar distances of comets in such orbits, even though the stars also remove many to the depths of space. Thus, possibly the gravitation of the planets first, and then of the passing stars, is responsible for the existence of the comet cloud, deep frozen at the limits of the solar system. This solution to the comet-cloud problem, however, is still weak in providing the huge planetary-energy budget needed to throw out so many comets.

The most promising theory to avoid this energy crisis has been proposed recently by A.G. W. Cameron. He suggests that in the collapse of the original great interstellar cloud, there developed many other fragmentary or smaller clouds. Some of these may have become dense, cold and quiescent enough to have hatched flocks of comets. Many of these comets could have moved in great orbits, gravitationally attached to the solar system; specifically, the comets we know to exist today. This concept of a comet "incubator" is very appealing and deserves much more study both theoretically and observationally.

Looking forward to observational tests, we note that comets produced in the incubator might be quite different in character from those produced in outer-planet regions of the solar discus.



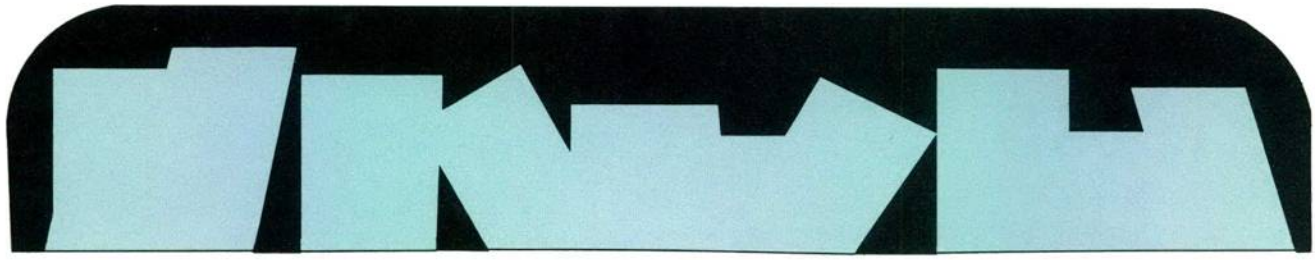
Hale Observatories Photograph

If slow cooling occurred around the Uranus-Neptune region, comets might have developed earthy or asteroidal nuclei before the ices froze and collected on them. Furthermore, the chemistry of this slow cooling would have tended to produce the most stable parent molecules, such as water, ammonia and methane.

The incubator in deep space may well have remained rather cold. Consequently, the comets could have accumulated dust grains, each surrounded by the exotic molecules now observed by radio in cold dust-gas clouds of interstellar space. More than two dozen of these molecules have been identified and more are found each year as microwave radio astronomy progresses.

Thus, incubator comets may tend to show exotic parent molecules and not contain earthy or asteroidal cores. Their deaths will be complete when all their ices evaporate, carrying with them the last of the accompanying dust. Nothing will be left except a dissipating meteoroid stream in space. On the other hand, comets found in the outer-planet region should show stable parent molecules and may die very slowly, as we have seen, fading away to small inactive asteroids. Furthermore, the incubator comets may show abundances of the different elements from those formed from the solar nebula. The solar mix of gases need not be representative of the gases in the outer clouds. Supernovae explosions in the huge fragmentary cloud of young stars may have distributed different atomic abundances in different localities. For example, short-lived atoms such as iodine-129 (half-life of 16 million years) or plutonium-244 (half-life of 82 million years) may have been more concentrated in some regions than in others. Their daughter atoms, various isotopes of xenon actually detected in meteorites, may tell a different story in comets. Clearly, we need to learn more about comets if we are to pinpoint their place of birth.

Perhaps we actually see comets from both possible sources, or perhaps some of the "planetary" comets never developed earthy cores. In any case, the general processes of cometary birth are fairly clear. Now we need to send space missions to comets so that we can look for the subtle clues that will tell us where they were born and give us more detail about the processes involved. Unmanned missions with scientific payloads to comets and asteroids are technically feasible today. Flyby missions will actually be cheaper and easier than the missions already sent to Mars and the planets — a tiny fraction of the effort involved in the manned Apollo missions to the moon. Happily, NASA is actively planning for future missions to comets and to asteroids, possibly first to Comet Encke in 1980. When we learn more details about the nature, birth, and death of comets, we will also understand better how our solar system, and probably how we ourselves, came into existence.



LETTERS TO THE EDITOR

Sir / Ken Mahood, board president of the American Astronomical Research Group asked me to look over his copy of your first edition (August 1973) of ASTRONOMY. You, sir, and your staff are to be congratulated for producing a very fine and useful science publication. As an amateur astronomer and a board member of the above group, I am happy that someone has at last come up with a reasonably nontechnical and exciting monthly periodical in our field.

The articles are easy to read and understand; the photos, art and layout are simply beautiful and the sky charts are very clear and most interestingly designed and described.

I could go on praising ASTRONOMY, but I'm sure you know what you have achieved as well as anyone.

AARG is promoting local school courses in astronomy in several Bergen County systems. We intend doing so all over the country as we expand. We certainly will suggest your new publication as a major supplement for text materials.

ROY FUHRMAN, D.M.D.
New Milford, N.J.

Sir / In the last few months I have received and read your magazine. Frankly, I like it very much. Its clean, clear writing is informative and very much to the point. Your articles for the most part are interesting reading. Of your monthly articles my favorite is Photograph in Astronomy. Many of your suggestions on exposure time and films to use are helpful in my attempts in astrophotography. Keep up the good work. I am looking forward to the articles in the months ahead.

JOHN J. GIANGIOBBE
Wayne, N.J.

Sir / Your magazine is excellent. Hope you continue the same format and simple language. A great help to beginners like myself.

CHRISTIAN MILLER, O.D.
Somerville, N.J. 08876

Sir / I would like to thank the staff of ASTRONOMY for doing such an excellent job in preparing my article "In Transit of the Sun" which appeared in the November issue.

Incidentally I was delighted to see ASTRONOMY expand to 64 pages. I especially enjoyed the new Astro-News section which will allow enthusiasts to follow the many developments which are occurring with such frequency in astronomy and the related space science field. I'm sure Astro-News will prove to be a very popular section.

Congratulations on producing such a fine new magazine.

FRANK APSI
Manchester, Conn.

Sir / I must compliment you on issue number four (November) of ASTRONOMY; it was your best yet. Astro-News is a feature your magazine needed to be both informative and up-to-date. The other articles were well written as usual, and I liked the choice and use of photographs.

Yours is a magazine that nonprofessionals and laymen can understand and enjoy. Don't change it.

BOB JUTTON
Syracuse, N.Y.

Sir / I guess I am added to the hundreds of readers praising your fine magazine. I am impressed by the fact that you publish the information in such detail and at the same time making it simple to understand, which is so helpful. Another interesting feature is Astro-Mart. What other magazine could do such a service to the subscribers? Keep up the fantastic job!

STEVE HUTSON
Monticello, Ill.

Sir / Your magazine was a big hit with the Astrophysics section of the Lyndon Johnson Space Center here in Houston. I think I may have gotten you a few subscriptions.

WILLIAM C. GIBSON, W.C. Gibson Instruments, Seabrook, Tex.

Sir / I think ASTRONOMY is the most beautiful magazine in the world. I have subscribed to hundreds and you have the best of the bunch.

MATT WILLIAMS
Muleshoe, Tex.

Sir / I have received my first issue of ASTRONOMY and am enjoying it very much. I loaned it to a friend last night and urged that he subscribe. He is strictly a rank amateur, just like I am.

I received my first issue on August 1, and that night I watched the shadow of Io in transit across Jupiter right on schedule, as in the article on Jupiter. This was interesting, and impressed me.

Best of luck with this publication.

R.M. NEUDECKER, M.D.
Jackson, Tenn.

Sir / I have received the initial copy of the magazine ASTRONOMY. I can only view with mingled awe and admiration your venture into the magazine field at "this point in time", as they say at the Watergate.

Good luck to you.

JAMES STEWART
Arlington, Va.

Sir / On Saturday morning, Nov. 10, 1973, I observed the transit of Mercury with Dr. Rosalind Mendell, cosmic ray physicist from New York university, from the Ardsley high school in the village of Ardsley, Westchester County, N.Y. (west longitude 75° 50', north latitude 41° 00' ±2'). There the seeing was supposed to be better than in New York City. (Originally I had planned to time it from the top of the Meyer Physics building at NYU, but had some doubt as to whether water towers on neighboring buildings might get in the way of the sun at the wrong moment.) By the light of the full moon we surveyed the schoolgrounds and found a parking lot with a low eastern horizon completely clear of trees and in an area where traffic would not bother us. Fortunately for us, the school is at the top of a low hill, and is thus favorably placed. We did have some slight fears about the weather as Friday had been quite cloudy, although it was nearly totally clear that evening.

After a scant six hours' sleep that night we arose and drove out to the school and set up our equipment in the cold (25° Fahrenheit) predawn light. We had on hand two Questars, two Linhof tripods, two Nikon camera bodies, a tape recorder and a shortwave radio. Mechanical problems with one camera precluded its use and so one of the Questars simply served for visual observations. The photographs obtained with the other camera were not satisfactory for publication.

There were a few clouds near the horizon and the rising sun was occasionally obscured for about the first half hour. After about 7:15 a.m. EST the sun was at last free of them and observations were no longer hampered.

Rosalind was interested more in watching the transit than in observing it, so it was I who made the timings. What surprised me from the first moment that I focused the sun in the field was how **obvious** Mercury was. After having read that its apparent diameter would be a mere 1/200th the diameter of the sun and having seen photographs of previous transits, I expected that I'd have to do some searching before I found it. Part of its conspicuousness might have been due to the fact that it had no competition from sunspots as the sun's disk seemed perfectly unblemished. Nevertheless, Mercury had a definable round black disk bigger than I expected, whose edges appeared to be composed of gyrating serations from the turbulence of the atmosphere.

By 8:15:10 EST Mercury was less than a diameter from the edge of the sun's disk. At 8:15:49 EST I timed third contact: a little part of Mercury leapt out to the blackness beyond the solar limb and poised there, an elongated droplet that slowly became more flattened as the seconds passed. The edge of the sun appeared to be sawtoothed and crawling in one direction. As Mercury proceeded over the limb and merged with the blackness on the other side, I could distinguish it only as the single notch in the sawtoothing that remained still. The illusion was very much that of a shadow rock in the midst of a stream with water flowing past. Eventually I could see not even that stationary notch, and timed fourth contact at 8:17:33 EST. My duration between third and fourth contacts was 1 minute 44 seconds.

As time signals could not be gotten at the observing site, I used my wrist watch to time the events and later corrected it to the time broadcasted by Canadian radio station CHU. Because of the uncertainty in the observations due to poor seeing and the method of timing, I would estimate the margin of error as ±5 seconds.

All in all, it was a memorable event, but I do hope that my equipment is functioning better at the next transit visible in the United States on May 7, 2003!

TRUDY E. BELL
SCIENTIFIC AMERICAN
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AUTHORS

Fred L. Whipple — Dr. Whipple, professor of astronomy at Harvard University and director of the Smithsonian Astrophysical Observatory (SAO), is internationally known for his research on the moon, meteors, and comets. His techniques for photographically measuring speeds and decelerations of meteors, methods for computing orbits of comets and asteroids, and theoretical model for describing comet structure are considered scientific standards.

At SAO, Dr. Whipple supervises more than 60 scientists engaged in study of stellar interior, the upper atmosphere, meteoritics, celestial mechanics, geodesy, and related fields. He currently directs the program for visual and photographic satellite tracking for NASA.

Born in Red Oak, Ia., he received his Ph.D. from the University of California, and additionally has received numerous honorary degrees.

Dr. Whipple's many awards include: the J. Lawrence Smith Medal for meteor research; Donohue Medals for independent discovery of six new comets; the Distinguished Service Medal, and the Medal of the University of Liege, Belgium in 1960; the 1962 Space Flight Award for contributions to space flight and satellite tracking programs; the 1963 Distinguished Federal Civilian Service Award for conceiving and developing an optical satellite tracking system; the 1971 Kepler Medal of the AAAS for contributions to man's understanding of the solar system, and the 1972 National Civil Service League's Career Service Award for Sustained Excellence.

Special consultant to the Committee on Science and Astronautics of the House of Representatives, Dr. Whipple serves as member and officer of many societies, committees and panels including NASA, the National Academy of Sciences — National Research Council, the Air Force Scientific Advisory Board, the National Science Foundation, the International Astronomical Union, and the Committee on Space Research (COSPAR).

Author of **Earth, Moon, and Planets**, and over 150 scientific papers, Dr. Whipple has been editor of the *Astronomical Journal* and the *Astrophysical Journal.* He currently is editor of the *Smithsonian Contributions to Astrophysics*, regional editor of *Planetary and Space Science*, member of the editorial board of *Space Science Reviews*, and the editorial committee of the *Annual Reviews of Astronomy and Astrophysics*. Under his supervision SAO began its "Special Reports in Space Science" series.

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CONSTELLATION CLOSE-UP

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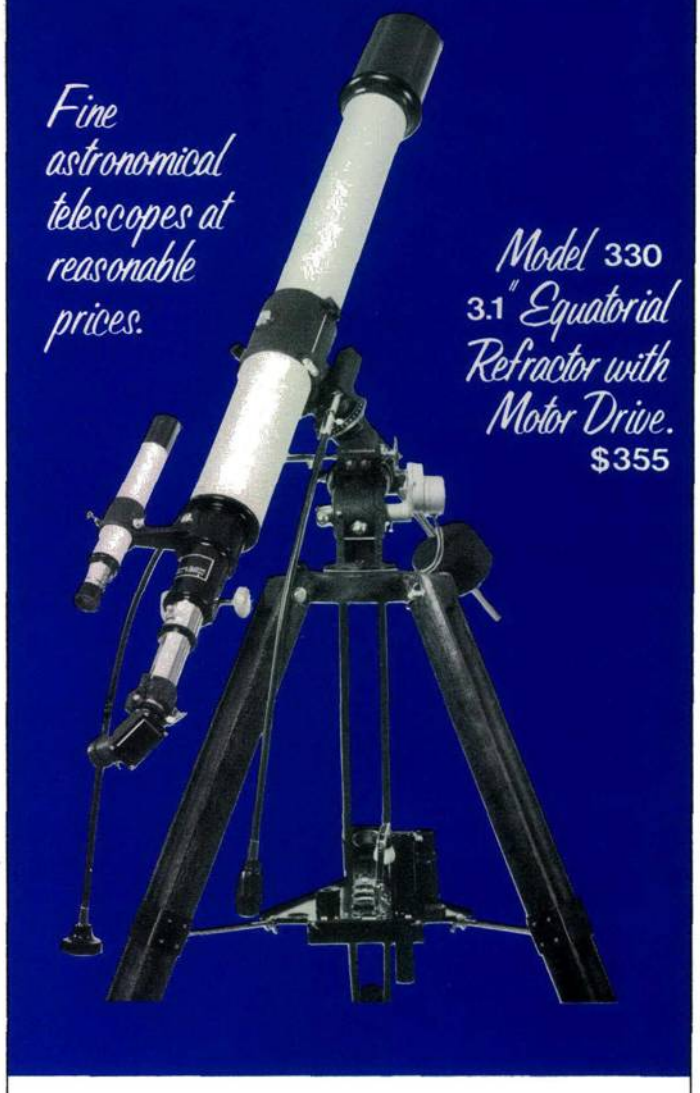

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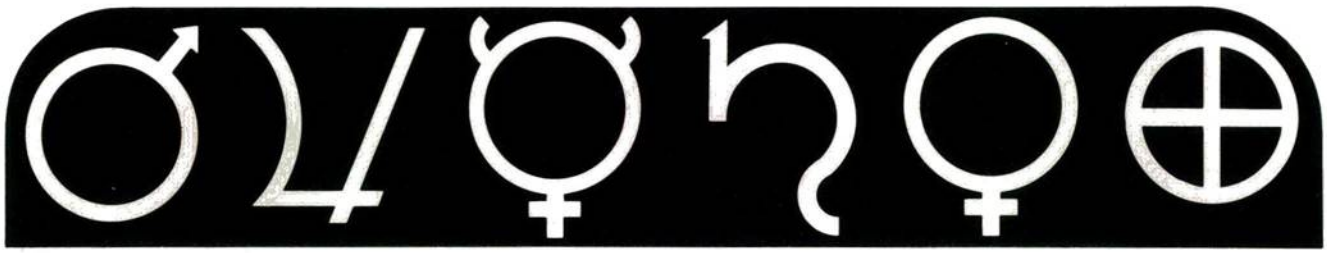


Comet Kohoutek Steals the January Sky Show

by
Terence Dickinson

January 1974 is a transition month. We go from planet-rich to planet-poor skies in a matter of weeks. However, the presence of Comet Kohoutek — our star performer from the frigid rim of the solar system — makes everything else so very ordinary by comparison.

Comet Kohoutek

Using tables and charts from the October issue, many of our readers got a glimpse of the "comet of the century" low in the southeast in late November and early December. At that time the comet was rapidly brightening and was showing signs of a significant tail. But twilight really spoiled what otherwise might have been a good sky show.

Now, in January, everything is working in favor of the backyard sky observer. The comet will be closer to Earth, the tail will be longer and brighter due to the Dec. 28 sweep to within 13 million miles of the sun's surface, and the viewing angle will be improved. Let's examine this last point — the viewing angle.

Although Kohoutek is 20 degrees away from the sun as seen from Earth on both Dec. 19 and Jan. 5, the comet's visibility is markedly different on these two dates as shown in the illustrations on page 30. On Dec. 19 the comet does not appear nearly as far above the horizon. However conditions are ideal on Jan. 5. The comet orbit is at a 70 degree angle to the horizon giving us nearly the full benefit of its 20 degree separation from the sun. A similar comparison can be made for other dates before and after the comet's encounter with the sun in late December.

The prime observing period for Comet Kohoutek is from the 5th of January to the 18th. During this interval the comet will fade by about five magnitudes — from -2 to +2 according to latest predictions. The tail should be at least 10 degrees long for part of this period.

The full moon will hamper observations until the 9th. From then until the 25th the moon will not be up when Kohoutek is, so luck is with us

The planet Venus reaches greatest brilliancy this month before it moves into inferior conjunction. In a small telescope or high power binoculars, our sister planet will look like a thin crescent moon. In the photograph at left, Gerald Gauerke captured the brilliant planet in the azure sky of dusk.

SATURN

January	1	16
R.A.	6^h02^m	5^h57^m
DEC.	+22°24'	+22°26'
DIST.	8.044A.U.	8.121A.U.
DIA.	18.5"	18.3"

MARS

January	1	16
R.A.	2^h00^m	2^h23^m
DEC.	+13°26'	+15°38'
DIST.	0.843A.U.	0.981A.U.
DIA.	11"	9.5"

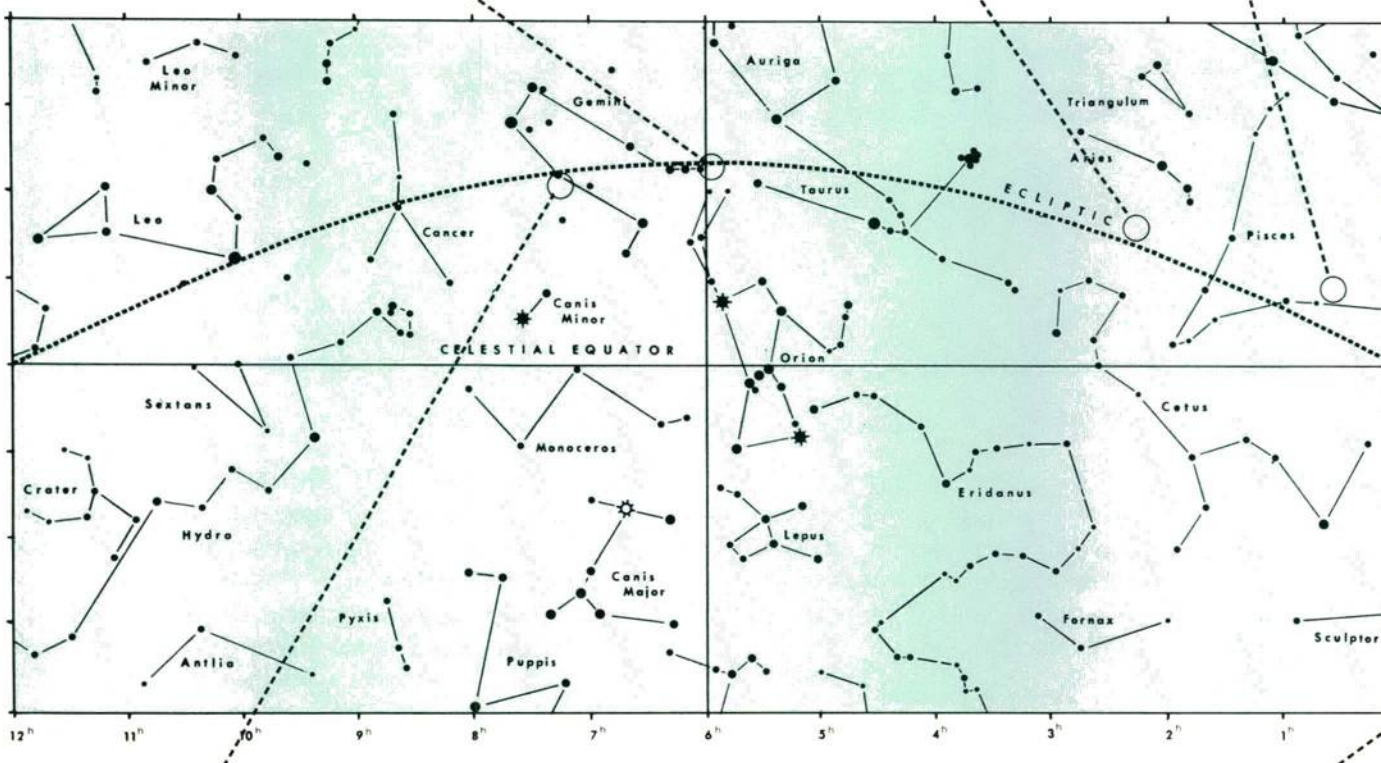
FIRST QUARTER

January 1

R.A.	0^h32^m
DEC.	+9°04'

VENUS

January
R.A.
DEC.
DIST.
DIA.



FULL MOON

January 8

R.A.	7^h15^m
DEC.	+20°36'

JUPITER

January	1	16
R.A.	21^h08^m	21^h22^m
DEC.	-17°13'	-16°13'
DIST.	5.827A.U.	5.937A.U.
DIA.	31.5"	30.9"

MERCURY

January	1	16
R.A.	18^h23^m	20^h09^m
DEC.	-24°42'	-22°16'
DIST.	1.436A.U.	1.395A.U.
DIA.	4.6"	4.7"

This planet finder chart shows the positions of the sun, moon, planets and brighter asteroids for the current month as they appear against the background of the zodiac. Positions are plotted for the 15th with additional ephemerides for the 1st. To find zodiacal constellations visible during the current month, see Star Dome.

	1	16
	20^h53^m	20^h37^m
	$-16°10'$	$-13°26'$
	0.331A.U.	0.275A.U.
	50.6"	61"

NEW MOON
January 23
R.A. 20^h18^m
DEC. $-16°36'$

PALLAS

January	1	16
R.A.	18^h02^m	18^h24^m
DEC.	$+3°31'$	$+3°55'$
DIST.	4.059A.U.	4.036A.U.

URANUS

January	1	16
R.A.	13^h42^m	13^h44^m
DEC.	$-9°59'$	$-10°06'$
DIST.	18.68A.U.	18.43A.U.
DIA.	3.6"	3.7"

VESTA

January	1	16
R.A.	12^h46^m	13^h01^m
DEC.	$+2°34'$	$+1°59'$
DIST.	2.116A.U.	1.915A.U.

NEPTUNE

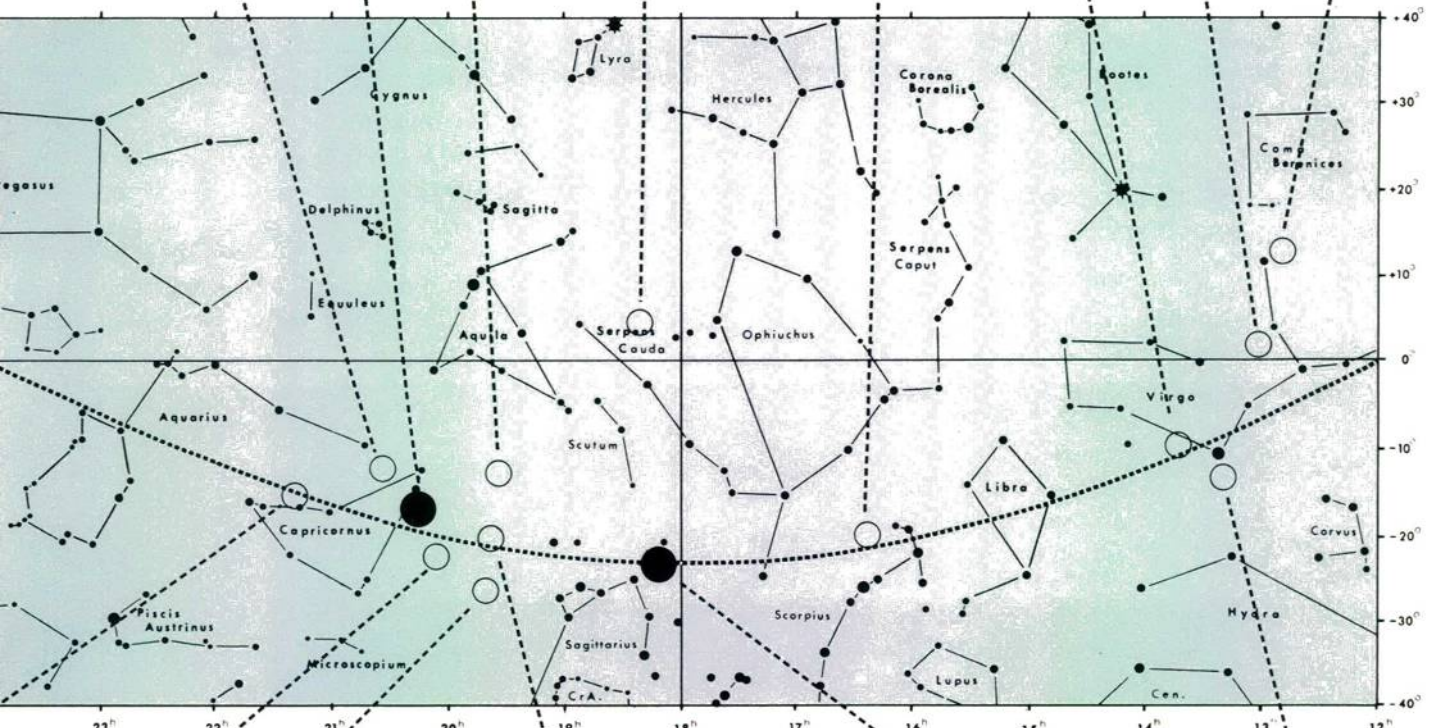
January	1	16
R.A.	16^h27^m	16^h29^m
DEC.	$-20°10'$	$-20°14'$
DIST.	31.13A.U.	30.97A.U.
DIA.	2.3"	2.3"

PLUTO

January	1	16
R.A.	12^h50^m	12^h51^m
DEC.	$+12°38'$	$+12°49'$
DIST.	30.96A.U.	30.63A.U.

JUNO

January	1	16
R.A.	19^h04^m	19^h28^m
DEC.	$-13°52'$	$-13°21'$
DIST.	3.944A.U.	3.916A.U.



NEW MOON
December 24
R.A. 18^h11^m
DEC. $-23°03'$

CERES

January	1	16
R.A.	19^h26^m	19^h52^m
DEC.	$-26°17'$	$-25°35'$
DIST.	3.891A.U.	3.916A.U.

THIRD QUARTER
January 15
R.A. 13^h24^m
DEC. $-13°56'$

SUN

January	1	16
R.A.	18^h44^m	19^h50^m
DEC.	$-23°03'$	$-21°03'$
DIST.	0.983A.U.	0.983A.U.
DIA.	32'	32'

for a change. Of course the persistent January clouds are the real hazard. Make every effort not to miss a clear evening.

During this optimum viewing period the naked eye is probably the best optical "equipment" to direct toward the comet. Binoculars are helpful (especially the 7 x 50 size) for bringing out detail in the tail. The binoculars may show the tails extending farther than the unaided eye can detect. While the comet is at its best a telescope is really superfluous — the small field of view restricts the observer to scanning only a small portion of the streaming object. The telescope may show some stars through the tail, and a star near the head provides an interesting telescopic comparison. But don't expect much detail. The sight to behold is the entire comet, a spectacle usually available only once each generation.

Kohoutek will be the most photographed comet in history. If you want your own personal record of this celestial interloper you can easily make one. See "It's Simple to Photograph Constellations" in the November issue of ASTRONOMY. Everything in that article applies to comet photography.

Venus

While examining Comet Kohoutek take a few moments to turn a telescope toward Venus. Don't wait too long or the planet will be gone; try before Jan. 10. Even a small telescope will do.

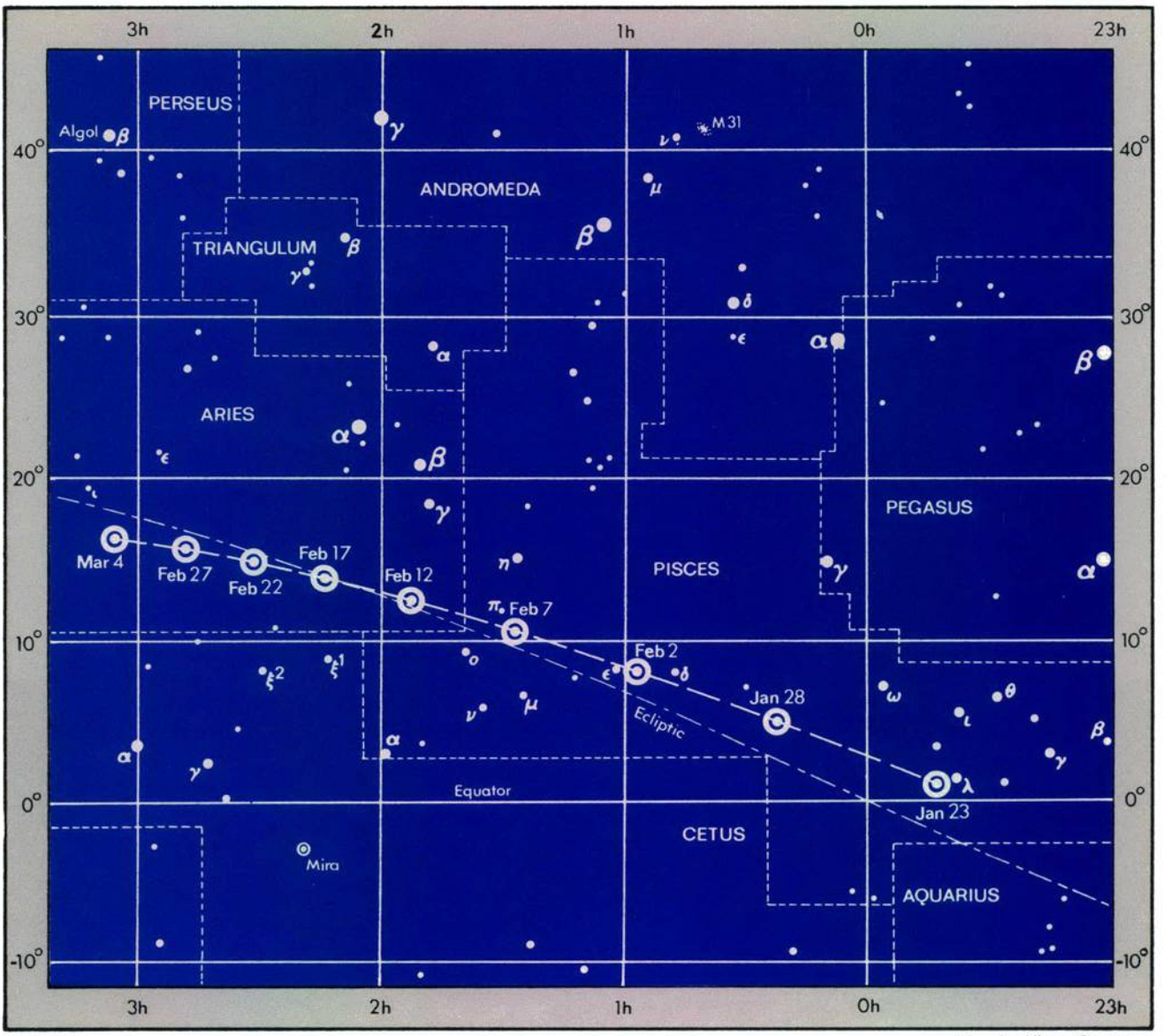
In the darkening sky a thin, delicate, snow-white crescent will float into the field of view. It will appear huge compared to your last view of the planet. On the 1st Venus is a 14 percent illuminated brilliant white crescent 50 seconds of arc in diameter. By the 10th it's a 7 percent sliver 57 seconds of arc across. A few days later the planet is lost in the solar glare and by the 23rd it is very nearly between Earth and the sun. Although unobservable except in specially prepared telescopes, Venus on that date will be a virtually invisible slice less than 1 percent illuminated and nearly 63 seconds of arc in diameter — the largest any planet can ever be, as viewed from Earth. At 24 million miles it is also the nearest any planet ever gets.

Saturn

After Venus and Kohoutek are gone — Earth's rotation carrying them below the western horizon — all telescopes should turn to Saturn, if only for a brief look. Quite often what is intended to be a brief glance turns into a lingering gaze as the tantalizing planet again and again

The above photographs of Mars were taken when the red planet was near opposition-this October. August Schug used an eight inch f/15 Cassegrain reflector telescope to make the photographs. All photos were made using eyepiece projection for an effective focal length (efl) of 145 inches. Except for the three second exposure at far left, all shots were two second exposures. H & W Control film was used for all but the far right photograph which was made on High Contrast Copy film. For the photograph right center, Mr. Schug used a 23-A red filter.

Photographs by August Schug



Map by Victor Costanzo

As Comet Kohoutek recedes from both Earth and the sun it will become gradually fainter. But at the same time, it will be seen higher in the evening sky. During the period indicated on this map, the comet will fade from first to sixth magnitude. Binoculars or low power telescopes are helpful. Keep a lookout for sudden changes in brightness that can never be predicted. For additional information on Comet Kohoutek, see Gazer's Gazette for October.

captures the eye and the imagination.

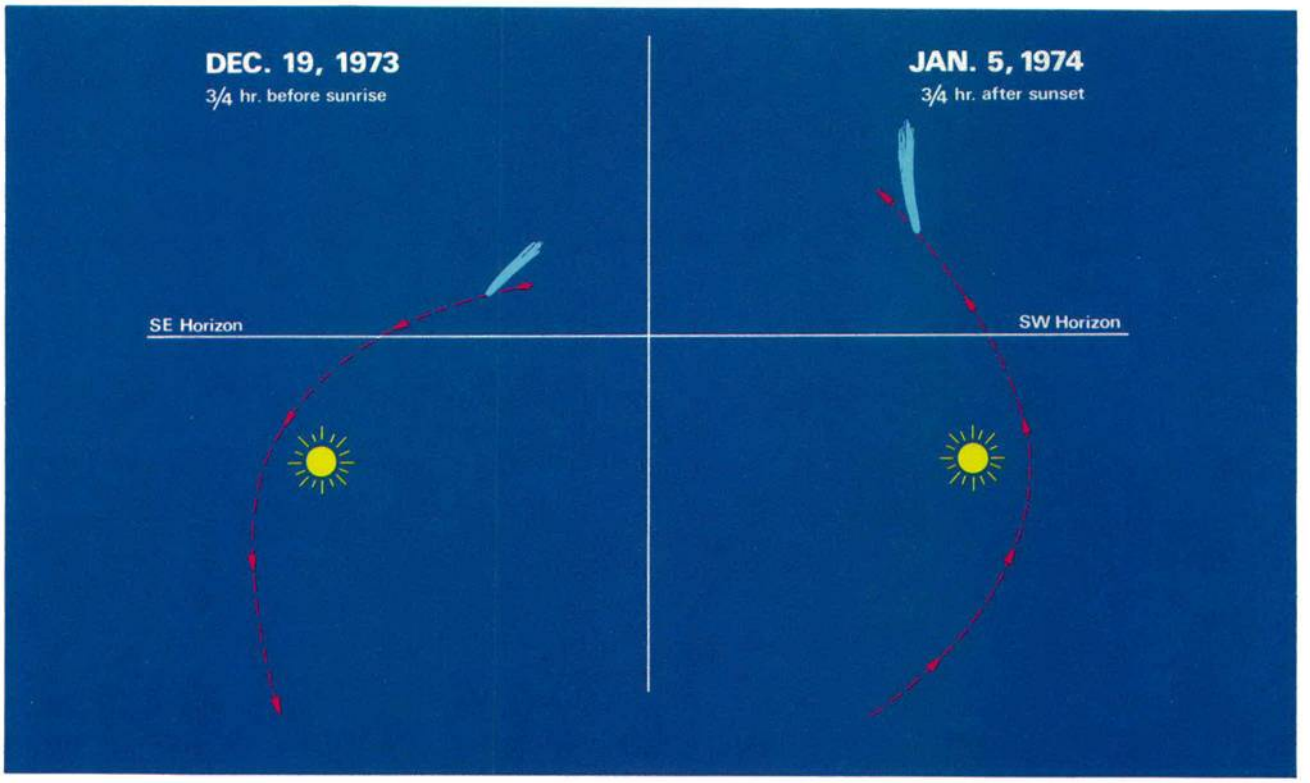
Saturn is high in the east all evening, shining brightly at magnitude -0.2 on the 1st and fading slightly to 0.0 by the 31st. The rings are open to their maximum extent as told in last month's ASTRONOMY. On the 1st they are 47 seconds of arc in apparent width decreasing slightly to 45 seconds of arc by the 31st due to an increase in the Earth-Saturn distance from 747 to 769 million miles.

Although it really doesn't mean much, Saturn passes its perihelion position (closest point to the sun) on Jan. 8. The event's insignificance is equalled by its rarity — Saturn won't be back in this position for 29.46 years. The planet's distance then will be 837 million miles from the sun instead of the average 886 million.

Jupiter

The removal of Venus from the evening sky is duplicated a few days later as Jupiter descends into the twilight glow. Unlike Venus this is the worst time to try to view the giant planet because it is on the other side of its orbit and is much nearer the horizon than it was last summer. So, telescopically anyway, Jupiter is not worth bothering with this month (or for the next several months either).

To the unaided eye Jupiter and Venus are an interesting pair as they "waltz" in their orbital paths into the sunset. Venus does most of the moving around. Watch as it closes in on Jupiter day by day until about the 5th, and then dives sunward.



Artwork by Victor Costanzo

One reason why Comet Kohoutek will be brighter in January than it was in December is shown in these two illustrations. The comet's apparent distance from the sun on both dates is the same — 20 degrees. But the orbital angles involved make the comet much easier to see in January. The comet will be nearer Earth in January as well and its tail should be longer and brighter because of its close approach to the sun Dec. 28. It all adds up to a prime observing period in early January. These diagrams represent the average situation for latitudes 35 degrees to 50 degrees north.

Mars

Still in the evening sky in Aries, Mars is now much fainter than it was last fall during its close approach to Earth. Because of its increased distance in January (over 80 million miles), Mars is out of reach of all but the largest telescopes. Smaller instruments will simply show a pink globe slightly gibbous in shape. Yes, Mars does have phases. They reach maximum about three months before and after opposition (closest approach to Earth). That maximum is easily detected in modest telescopes. Mars looks like an orange gibbous moon 85 percent illuminated.

Mercury, Uranus, Neptune and Pluto

None of these less easily seen planets are in opportune positions in January. During 1974 they will be seen with the unaided eye (Mercury) or telescope (Uranus and Neptune) or large telescopes (Pluto). Watch future issues of ASTRONOMY for details.

Almach

Double stars are too often relegated to the bottom of the sky observer's list. Since double stars are always there, year in and year out, there is no urgency attached to scrutinizing them. Planets, on the other hand, tempt telescope scanners because of their rare periods of prime visibility as often mentioned in this section. This month we will pinpoint a truly beautiful double star worth a few minutes in any telescope.

Almach is probably better known as Gamma Andromedae, the "end" star in Andromeda. It's well positioned for observation in January just to the northwest of the Pleiades and south of Cassiopeia. (See Star Dome for its position in January skies.)

Through a three inch or larger telescope the striking difference in magnitude and color makes this a beautiful double. The bright star is deep yellow, magnitude 2.1, and the faint 5.1 magnitude companion is a contrasting blue. The separation is 10 seconds of arc so the faint star is nestled fairly close at low powers. The orbital period is too long to be measurable.

In 1842 F. G. W. Struve discovered that the fainter star is itself a pair of sixth magnitude stars only half a second of arc apart. The orbital period of these stars is 61 years. Actually the Almach system consists of four stars — one of the Struve pair being a double discovered by spectroscopic analysis.

So when you view this double star in a small telescope, the faint companion is in reality three unresolvable stars, each more luminous than the sun. The 2.1 magnitude yellow star is a giant over 600 times as bright as our star. The whole system is 260 light-years distant.

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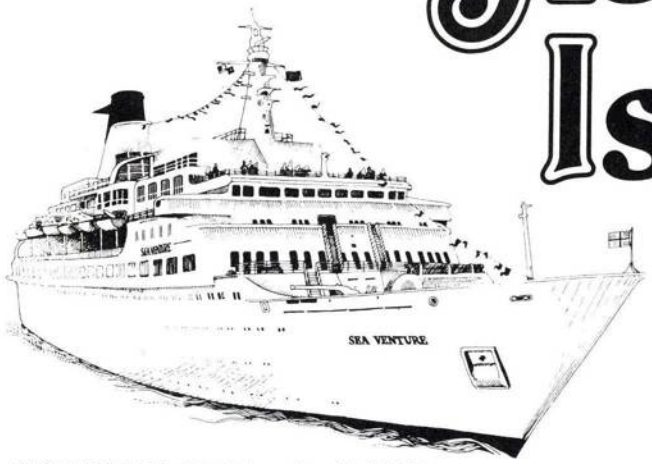

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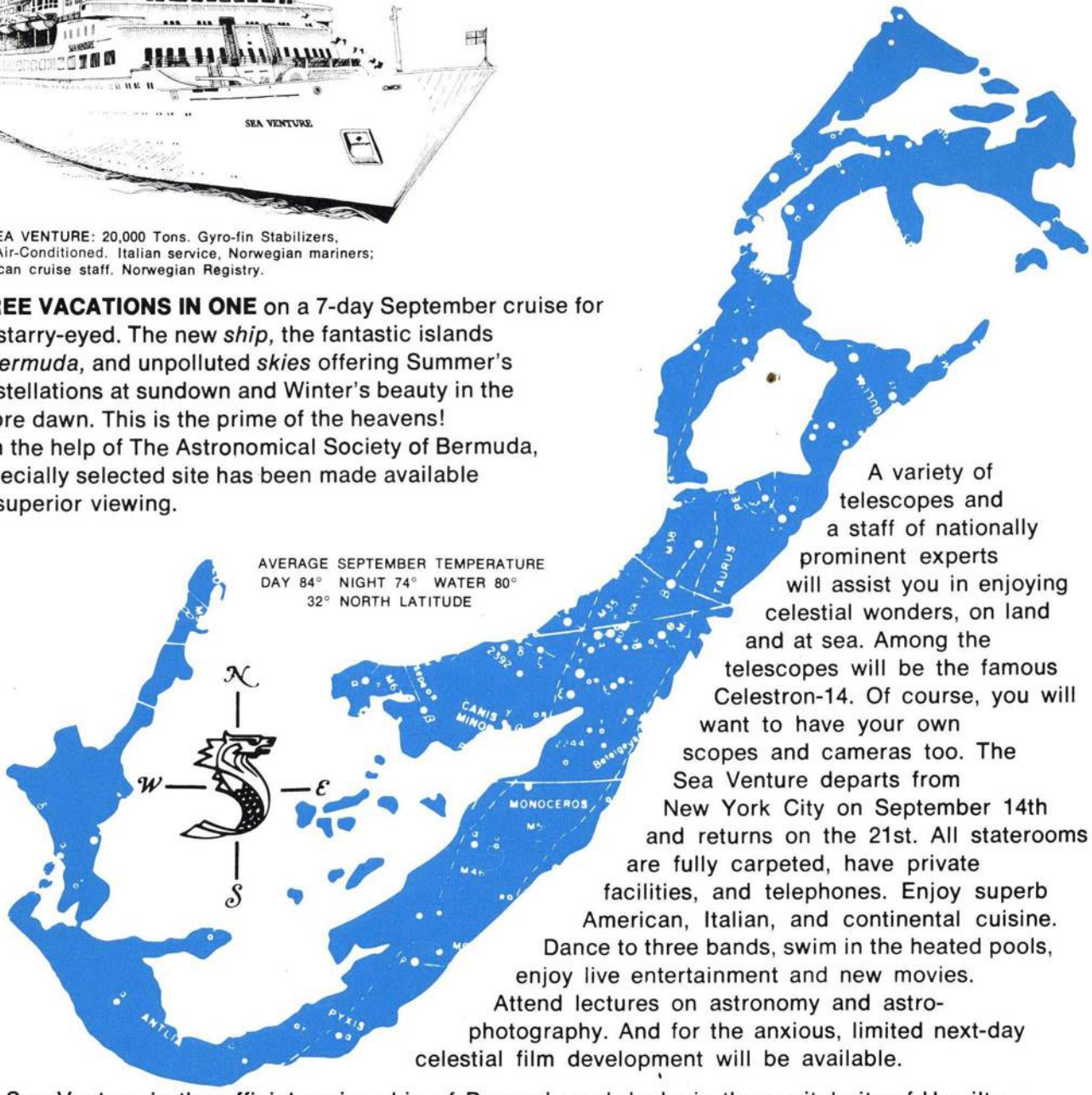

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JANUARY

Stars in each constellation are indicated, in order of brightness, with the Greek Alphabet.

α Alpha	η Eta	ν Nu	τ Tau
β Beta	θ Theta	ξ Xi	υ Upsilon
γ Gamma	ι Iota	ο Omicron	φ Phi
δ Delta	κ Kappa	π Pi	χ Chi
ε Epsilon	λ Lambda	ρ Rho	ψ Psi
ζ Zeta	μ Mu	σ Sigma	ω Omega

MAGNITUDES

- Zero
- First
- Second
- Third
- Fourth
- Fifth

OBJECTS

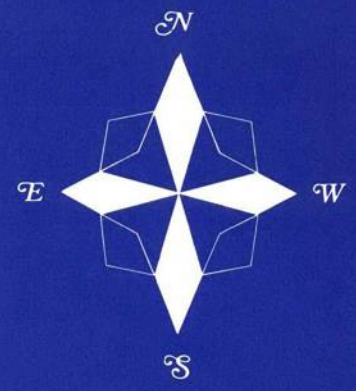
- Open Clusters
- Globular Clusters
- Diffuse Nebulae
- Galaxies
- Double Stars
- Variable Stars

Star Dome approximates the sky as it appears at 9 p.m. Local Standard Time on the first day of the current month. The same constellations are visible one hour earlier on the 15th. To use this constellation finder, hold it overhead so the compass points line up with North, South, East and West in your backyard or viewing area. For example, to find constellations in the southern part of the sky hold the chart in front of you so the South compass point faces the southern horizon. Repeat this procedure for East, West and North. Since only the brighter stars are represented in this map, you should be able to trace out the geometrical shapes of the contellations with ease. To find planets, asteroids, etc., visible among the current month's zodiacal constellations, refer to the planet finder in Sky Almanac.

Map by Raymond G. Coutchie

STAR DOME

Map Centered on 43° North Latitude



by
John G. Harmon

The galactic clusters called the Hyades and the Pleiades have attracted attention from very early times, both individually and together as the constellation Taurus. The constellation dates from about 4000 to 1700 B.C. when Taurus marked the vernal equinox. In a number of ancient cultures of that time we find the sun venerated in the form of a bull, or in a form that was half man and half bull.

This was the case in Assyria and Egypt where the Egyptians identified it with their god Osiris. It was also recognized by the Persians and Hebrews who knew it as the leader of the zodiac; as such it began their year.

Even the Druids had a great "Tauric Festival" which is still celebrated today as May Day. During this festival, "bull cakes" were baked. These too have survived the passage of time and today are known as hot cross buns.

In Greek myths, Taurus is said to be Zeus in the form of a snow-white bull — a shape which he assumed to kidnap Europa, the daughter of King Agenor of Tyre. It is reported that Zeus so charmed Europa that he induced her to climb upon his back. He then plunged into the ocean and bore her off to Crete. Europa had three sons by Zeus: Rhadamanthys, Sarpedon and Minos. The latter became the legendary king of Crete.

The traditional picture of Taurus shows the front half of the bull only. Perhaps this can be explained by the fact that Taurus is swim-

ming with Europa on his back, and his hind quarters are submerged.

Taurus was seen as a bull by most ancient cultures. One notable exception, however, was the Chinese, who saw this stellar group as either the White Tiger or the Great Bridge. Much later, after having contact with Jesuits, the Chinese referred to Taurus as the Golden Ox.

The brightest star or lucida of the constellation is Aldebaran from the Arabic Nair al Dabaran, the bright one of the follower (of the Pleiades). The Arabs also saw it as a big camel, with the other stars of the Hyades being little camels. Aldebaran was also one of the four Royal Stars of Persia which at that time marked the cardinal points of the heavens. Those points were the solstices and the equinoxes.

Beta Tauri is El Nath, the butting one, and marks the tip of the northern horn. El Nath is also part of Auriga where, as Gamma Aurigae, it is called Al Kab dhil Inan or the heel of the rein-holder.

As was mentioned earlier, Taurus is primarily formed by two galactic or open star clusters, the Hyades and the Pleiades. They were known to people of the Euphrates as the Great Twins of the Ecliptic.

The V-shaped Hyades form the bull's face with reddish Aldebaran marking the eye. Although it lines up well with the group, Aldebaran is not physically a member of the cluster.

The Hyades were identified with rainy weather and were even worshipped by the Chinese as the "General or Ruler of Rain". The Chinese had a number of other names for the group as well, including the "Rabbit Net" and the "Announcer of Invasion on the Border".

Mythologically, the Hyades were daughters of Atlas and half sisters of the Pleiades. It is said they were changed into stars because of their grief for their brother Hyas. An alternative legend states that they were the nurses of the god Bacchus when he was an infant.

Sitting on the back of Taurus is the cluster we call the Pleiades. This small dipper-shaped asterism has attracted more attention than any other group of stars.

The Hindus saw them as a razor; in China they were worshipped as the "Seven Sisters of Industry" as early as 2357 B.C. The Pleiades were identified by Egyptians with the goddess Nit, one of the principal deities of lower Egypt. In this context they are closely associated with the Great Pyramid. The Pleiades could be seen through the south passageway at their culmination 4,144 years ago. Some authorities have also suggested a relationship between these seven stars and the seven chambers of the Pyramid.

The Pleiades are most often referred to as the seven sisters, and are said to be daughters of Atlas and Pleione. The nine brightest stars in the cluster bear the names of the sisters and their parents. They are, in order of increasing magnitude, Alcyone, Maia, Electra, Merope, Taygete, Celaeno, Sterope I & II (a double sometimes referred to collectively as Asterope), Atlas, and Pleione.

It is interesting to note that there is always a reference to seven stars, though only six are easily discernable to the naked eye. This has led to speculation that one or more of the Pleiades has dimmed over the centuries. Several of the sisters have been called the "lost Pleiad". Electra is said to have hidden her face so as not to watch the fall of Troy. Merope supposedly dimmed because of her marriage to a mortal, while Celaeno is said to have been struck by lightning. Sterope, however, is the dimmest of the seven, and is therefore most likely the lost Pleiad.

Just as the Hyades were associated with rain, the Pleiades had an almost universal association with the commemoration of the dead. All over the world, festivals of death and destruction were celebrated in November, the month in which the Pleiades culminate at midnight. Even in Persia, the entire month of November was known as Mordad, which means the Angel of Death.

The Aztecs believed that every 52 years (usually on Nov. 17, when the Pleiades were overhead at midnight), the world would end. Human sacrifices were made to forstall their doom. Similarly in Egypt, again around Nov. 17, a solemn festival lasting three days was held to commemorate a deluge or calamity. In the Talmud, it is said of the great flood that "He took two stars out of the Pleiades and thus let the deluge loose...." Also, an old Mexican tradition holds that the world was once destroyed when the Pleiades culminated at midnight. The Japanese Feast of Lanterns is also related to a calamity associated with the Pleiades.

Even the Druids had similar beliefs. On Nov. 1 they celebrated the reconstruction of the world. Like a number of other Druidic festivals, it survives today as our "All Saints Day" which, preceeded by "All Hallows Eve" and followed by "All Souls Day", again constitute a three day festival of the dead.

The fact that these festivals are all so similar and are found in so many unrelated cultures is something that cannot be explained away as a matter of mere coincidence.

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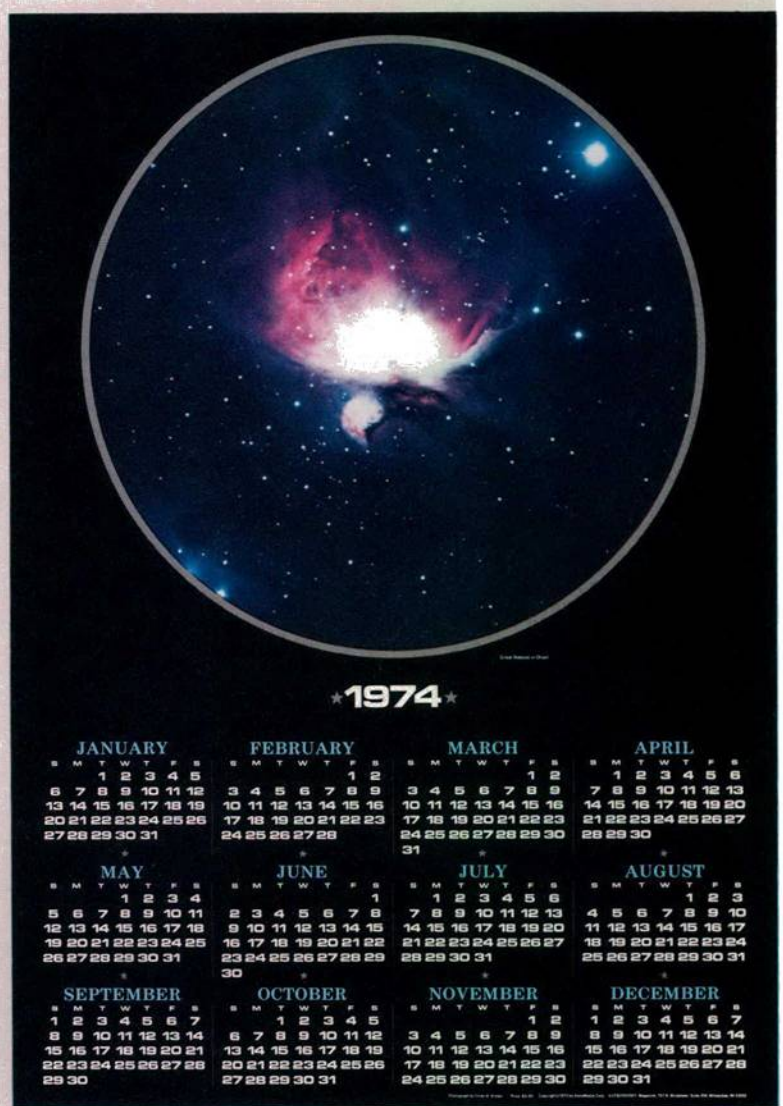

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Observing Nebulae and Clusters

by
Thomas C. Bretl

Nebulae and clusters within our own galaxy, and the countless "island universes" lying far beyond it, are among the most interesting and popular targets for amateur-size telescopes.

Some, like the Orion nebula, are true celestial spectaculars — guaranteed "crowd pleasers" that never lose their appeal. Others, like the dim planetaries or remote galaxies, offer an exciting and challenging hunt that soon brings an appreciation of telescope aperture, rather than magnification, and subtle beauty and mystery, rather than dazzling brilliance.

There are five major types of nebulae and clusters: open clusters, globular clusters, diffuse nebulae, planetary nebulae, and extragalactic nebulae. Each has its own appeal, and each can be best explored with slightly different equipment.

Open Clusters

Open clusters are especially plentiful in January skies and are terrific objects for small telescopes, and even 7 x 50 binoculars. They include large coarse clusters, like the Pleiades and the Praesepe (M-44); richer and more compact clusters, such as M-35 in Gemini (see Constellation Close-Up) and the famous double cluster in Perseus; and very rich, compact patches of "gold dust" like M-37 in Auriga, perhaps the most beautiful of all.

Many of these clusters have angular sizes of more than 20 minutes of arc, so very low power (three to four times your telescope lens or mirror diameter in inches) is almost always best. If too great a magnification is used, a cluster may more than fill the entire field, leaving the observer to "see the trees, but miss the forest"!

Clusters can be particularly elusive when they have a rich background. In the Milky Way, for instance, it is sometimes very hard to distinguish a cluster from its star-filled surroundings. Here a richest field telescope, equipped with a 60 degree Erfle eyepiece, can be used to best advantage. With low magnification and an extremely wide field of view, it allows you to witness the exquisite structure of our galaxy by not getting too close! M-34 Perseus is especially beautiful, viewed through such an instrument.

Globular Clusters

While the richest open clusters contain several hundred stars, globular clusters often contain hundreds of thousands. But because they are so compact, and much more distant than open clusters, many of them appear only as "fuzzy stars" in small telescopes. For these, low magnification is again the best — higher power only reduces contrast while revealing no detail.

There are, however, some magnificent exceptions! A four inch telescope will resolve loosely packed globulars such as M-4 and M-22 into countless sparkling pinpoints of light, while a six inch scope will do the trick on M-5 and M-13, two of the very best. Here it is well worth your time experimenting with higher powers. Try to find the most

Hale Observatories Photograph

The Horsehead nebula is an example of a diffuse nebula. This is not the easiest object to find because it is in the same field of view as Zeta Orionis. For its location, see ASTRONOMY's cover for November or January Star Dome.

Photograph by John Sanford

Globular star clusters are compact spheres of glittering stars. In a large telescope, they look like the M-5 photo above — like salt spilled on balck velvet. Since globulars are distant, a four inch or larger telescope is necessary to resolve individual stars. In a 60mm refractor, it is easy to mistake a globular cluster for a diffuse nebula.

Celestron Pacific Photograph

Photograph by Orien A. Ernest

Planetary nebulae are the puffed-out remains of catastrophic stellar explosions. In a telescope, these tiny nebulae resemble planets — at least in apparent size. As a result, medium and large aperture telescopes and high magnification are necessary to resolve detail. Above, the Crab nebula — a favorite target for beginners — is one of the largest planetary nebulae in the sky. It can be found in the constellation Taurus, just above Zeta Tauri.

pleasing balance between stellar brilliance and resolution.

Unfortunately, during the winter months, few globular clusters are visible. In fact on mid-January evenings, only one prominent cluster, M-79 in Lepus, is in good observing position. This scarcity is due to the distribution of globulars on each side of the galactic plane, mostly between the sun and our galaxy's center. As a result, we find the vast majority of these clusters scattered near the summer Milky Way, especially in the constellation Sagittarius.

Diffuse Nebulae

Diffuse nebulae are dark clouds of interstellar dust and gas which obscure more distant stars, or bright clouds which shine by reflected starlight or whose gases glow under the constant bombardment of stellar radiation. Three of the best known examples are the Orion, Lagoon, and Trifid nebulae, which are very bright, beautiful objects in any telescope, under both low and high magnification.

Island universes, star systems like our own Milky Way galaxy, are prime targets for the deep sky explorer. Prime galaxy targets during the winter months are M-81 and M-82 — a pair of galaxies in the constellation Ursa Major which are seen in the same telescopic field of view. The best telescope to use for galaxy hunting is a six or eight inch aperture richest field telescope with wide angle eyepiece and low magnification.

Many other diffuse nebulae are large and faint, however, and contrast very poorly with their surroundings. For these, low power is again recommended, and a dark, moonless night is a must. Averted vision (looking out of the corner of your eye) often helps, or try gently sweeping your telescope back and forth so that the nebula moves slowly across the field. Both techniques generally enhance the contrast between nebula and sky. The Veil, Pelican, and North American nebulae in Cygnus are good representatives of this "large and faint" group.

On January evenings, Orion is the best place to hunt for diffuse nebulae. In addition to the great M-42, there is M-43, M-78, NGC-2024, and the Horsehead nebula. For the latter two, a low power wide field is not the best because it includes Zeta Orionis, whose light "floods" the field. Using a high enough magnification to keep Zeta out of the way, however, NGC-2024 becomes easy in a six inch telescope.

Planetary Nebulae

While some of the diffuse nebulae are more than a degree long, most planetary nebulae have dimensions smaller than one minute of arc. They are also usually quite faint, so finding them is seldom an easy task. This is especially because under low magnification many planetaries appear quite starlike. With a little patience, however,

several dozen of these remnants of stellar explosion can be observed with small telescopes. Use a low power first, and then try increasing it to 10 or 15 times your telescope's diameter in inches.

The Ring nebula in Lyra is probably the most famous planetary nebula, but during January you can try looking for the Crab nebula (M-1), which is one of the brightest. Gemini's NGC-2392 is slightly more difficult, and the Little Dumbbell nebula (M-76) is a large but very faint planetary in Perseus.

Extragalactic Nebulae

All of the nebulae and clusters discussed so far are found either within or in the immediate neighborhood of our own Milky Way galaxy. But far beyond its boundaries lie millions of other galaxies, and more than one thousand of these are within the range of amateur-size telescopes.

These extragalactic objects vary in size from less than a minute of arc to almost three degrees. They can be as bright as fifth magnitude, or as faint as your telescope is able to detect. Some have brighter centers, while others are uniformly pale and show up poorly against the background sky. Most will appear only as fuzzy spots or elongated blurs in a small telescope, but a few will reveal a spiral structure in 10 or 12 inch instruments.

The best known example, of course, is the Great Nebula in Andromeda (M-31), which is still high in the western sky on January evenings. Others visible during the winter months include M-81 and M-82, a fine pair contained in the same low power field near 24 Ursa Majoris.

The appeal of the distant galaxies, and many of the other types of nebulae and clusters, lies mainly in the challenge of finding and identifying them. In many cases this is not easy. Fairly bright objects, of course, can usually be located in your finder, but for fainter nebulae and clus-

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TYPE	DIAM.	F.L.	EYEPIECE F.L.	EYEPIECE APP. FIELD	MAG.	REAL FIELD	RECOMMENDED OBJECTS
Refractor	60mm	900mm	25mm	45°	36	1°15'	Open and Globular Clusters Bright Diffuse Nebulae
Reflector	4-1/4"	45"	28mm	50°	41	1°13'	All Nebulae & Clusters
			18mm	45°	64	42'	Globular Clusters & the Brightest Diffuse Nebulae
Reflector	6"	48"	28mm	50°	44	1° 08'	All Nebulae & Clusters
			18mm	45°	68	40'	Globular Clusters, Compact Open Clusters, And Bright Diffuse Nebulae
Richest Field (RFT) Telescope	6"	24"	28mm	50°	22	2° 16'	Star Fields & Large Diffuse Nebulae
Reflector	8"	64"	32mm	50°	51	59'	All Nebulae & Clusters
			18mm	45°	90	30'	Globular Clusters, Bright Diffuse Nebulae And Planetary Nebulae
Richest Field (RFT) Telescope	8"	36"	32mm	60° *	29	2° 04'	Star Fields & Large Diffuse Nebulae Galaxies

* Requires 2" Focusing Mount.

Celestron Pacific Photograph

Open star clusters are especially plentiful in January skies. Since they are generally bright, many can be found without optical aid. The double cluster in Perseus (above) can be found without a telescope and is especially interesting in 7 x 50 binoculars. To enjoy a wide variety of open star clusters, all an observer needs is a small telescope with low power. For additional information on the proper equipment for open star clusters, see the table on the opposite page.

ters there are three basic discovery techniques.

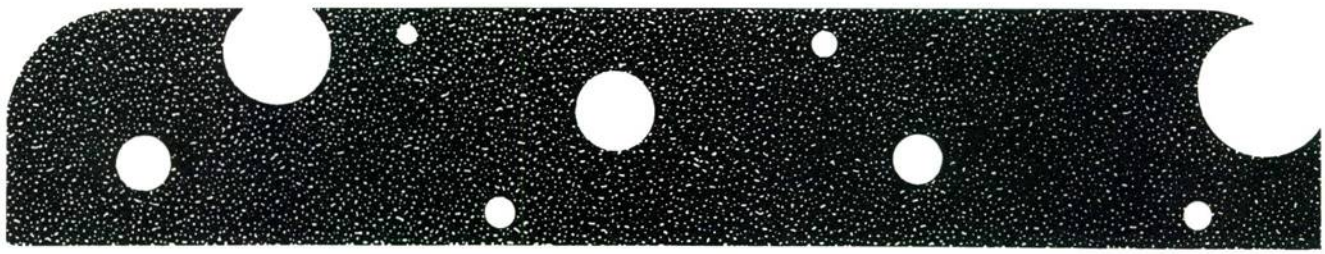
The first, and probably least satisfactory (especially with a portable telescope), is the use of setting circles. Unless your circles are large and very precisely adjusted for the proper date and time, they can do no better than put you in the right general vicinity. And from there you have no idea which way to go!

The second technique is the "drift method". Here you center your telescope on a star somewhat to the west but almost with the same declination as the nebula for which you are searching. After noting the number of minutes of arc separating the star from the desired object, you simply wait that amount of time, allowing the object to "drift" into the field of view. Unfortunately, there are obvious drawbacks to this plan. You have to wait! And often there is no convenient star on which to center.

For the adventuresome in spirit, the third technique is by far the best: using a good star atlas, become familiar with the area surrounding the "hunted" nebula. Then, starting with the nearest star prominent enough to be easily located in your finder, just "hop" from star to star toward the desired object. If you keep in mind your telescope's field of view (the wider, the better), and don't become confused by the inverted telescopic image, you will be surprised how far you can sweep this way and still know exactly where you are looking. Usually you shouldn't have to go too far, and if you make note of the stellar patterns you encounter along the way, you will never have trouble finding that particular nebula again.

Regardless of which searching method you use, when observing faint nebulae and clusters it is very important that your eyes be dark-adapted. Even a brief look at a bright star through your telescope can make it more difficult to pick out a fainter object immediately afterward.

"Seeing" conditions also make a very big difference. A clear, "sparkling" night, with no moon, is a definite plus. So should you fail to find that elusive fuzzy patch some night, don't despair. The next night it may be easy.



STELLAR FRONTIERS

Interacting Galaxies

by
Gerrit L. Verschuur

Our nearest extragalactic neighbors are the clouds of Magellan, two irregular type galaxies about 175,000 light-years from us. On a truly clear night in the southern hemisphere, a night so clear that the Southern Cross is lost in the vivid band of the Milky Way itself, one can see both clouds with the naked eye in the constellation Dorado.

These two relatively small galaxies (30,000 light-years across) are in orbit about our own Milky Way galaxy in much the same way that a comet is in orbit about the sun. At the same time they appear to have a devastating effect on our galaxy when they pass close to us.

There are now many known cases of interactions between galaxies. Many interacting galaxies are seen in the **Arp Atlas of Peculiar Galaxies.** They often appear as two or three separate galaxies in a photograph, but with obvious bridges of material between them. In the illustration on page 44 (left) we see a black and white photograph, actually a negative print, of Arp 295, an interacting galaxy pair. In the lower half of the illustration we see the same pair, but in color. The colors have been artificially introduced so as to dramatize the bridge of material between the two galaxies. Different colors have been used to represent different levels of light in the original photograph. Because the picture processing equipment involved television techniques, the resolution of the color picture is not as great as the original.

The long sweep of emission between the two galaxies is an intergalactic bridge that streams through 400,000 light-years of space. Astronomers believe this bridge was produced when the two galaxies swept near to one another many hundreds of millions of years ago when the mutual gravity of the galaxies dragged out matter from their disk-like structures. The illustrations on page 44 (right) show NGC-4675 (known as the "mice") and the intergalactic arches that join them and radiate from them.

We now know that such intergalactic bridges are a norm of the universe, according to some recent theoretical work done by Alar and Juri Toomre. These scientists used a computer to simulate the effect of one galaxy on another when the two pass close to each other in space. Their

Astronomers now believe that gravitational interaction between galaxies in pairs or clusters accounts for the spiral patterns of stars. Here M-51's spiral structure may have been caused by interaction with the smaller satellite galaxy NGC-5195.

original intention was to examine what effect the Magellanic clouds would have had on our galaxy, if the clouds passed close to us. In the computer they used two disk shaped objects to represent our galaxy and the Large Magellanic cloud. Both disks consisted of many separate points which simulated the existence of matter (stars) in the galaxies. Then, by use of complex mathematics, they sent one disk past the other in three dimensional space to see what would happen. The results were surprising.

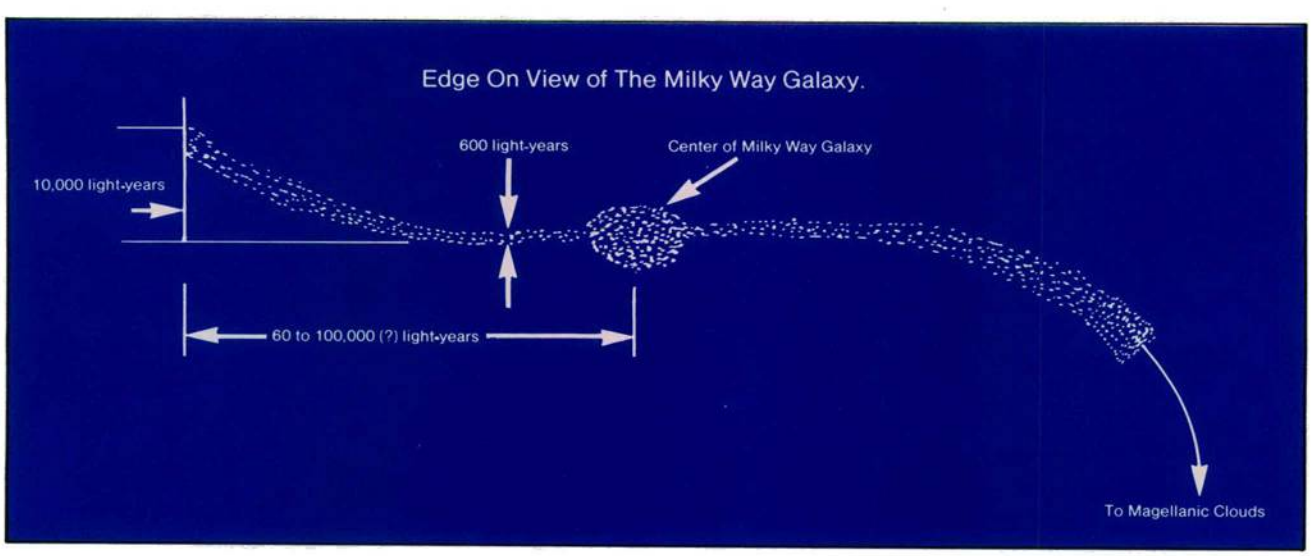
The original motivation for doing the computer experiment was to explain the fact that our galaxy appears to be shaped somewhat like a hatbrim. One edge of the brim bends up, the other down. This is not quite the traditional view presented by standard texts on astronomy, where our galaxy is always described as being a flat disk with a bulge at the hub. The edge of our galaxy, in the direction of the constellations Cygnus and Cassiopeia, bends to the north of the Milky Way. Matter in these distant regions is very patchy and moving with apparently strange velocities. The Toomre brothers were trying to account for the hatbrim effect in their experiments. The Magellanic clouds were passed close to our galaxy in various orbits, like a comet passing close to the sun, and they searched for a suitable orbit which might explain the bending of our galactic disk.

They found that if the Magellanic clouds passed by our galaxy in a direction opposite to the way our galaxy rotates, then the clouds would indeed interact with matter in our galaxy and cause its outermost parts to distort and take on the distorted hatbrim shape. They were further able to show that the Magellanic clouds must have come toward our galaxy from the northern part of the sky and crossed the Milky Way plane near the region of the constellation Perseus. At their nearest approach the clouds must have passed the plane of the Milky Way at a distance of about 40,000 light-years from the sun, or about 60,000 light-years from the center of our galaxy. We now see the clouds in the southern sky travelling away from us, perhaps to return to their original positions in about three billion years.

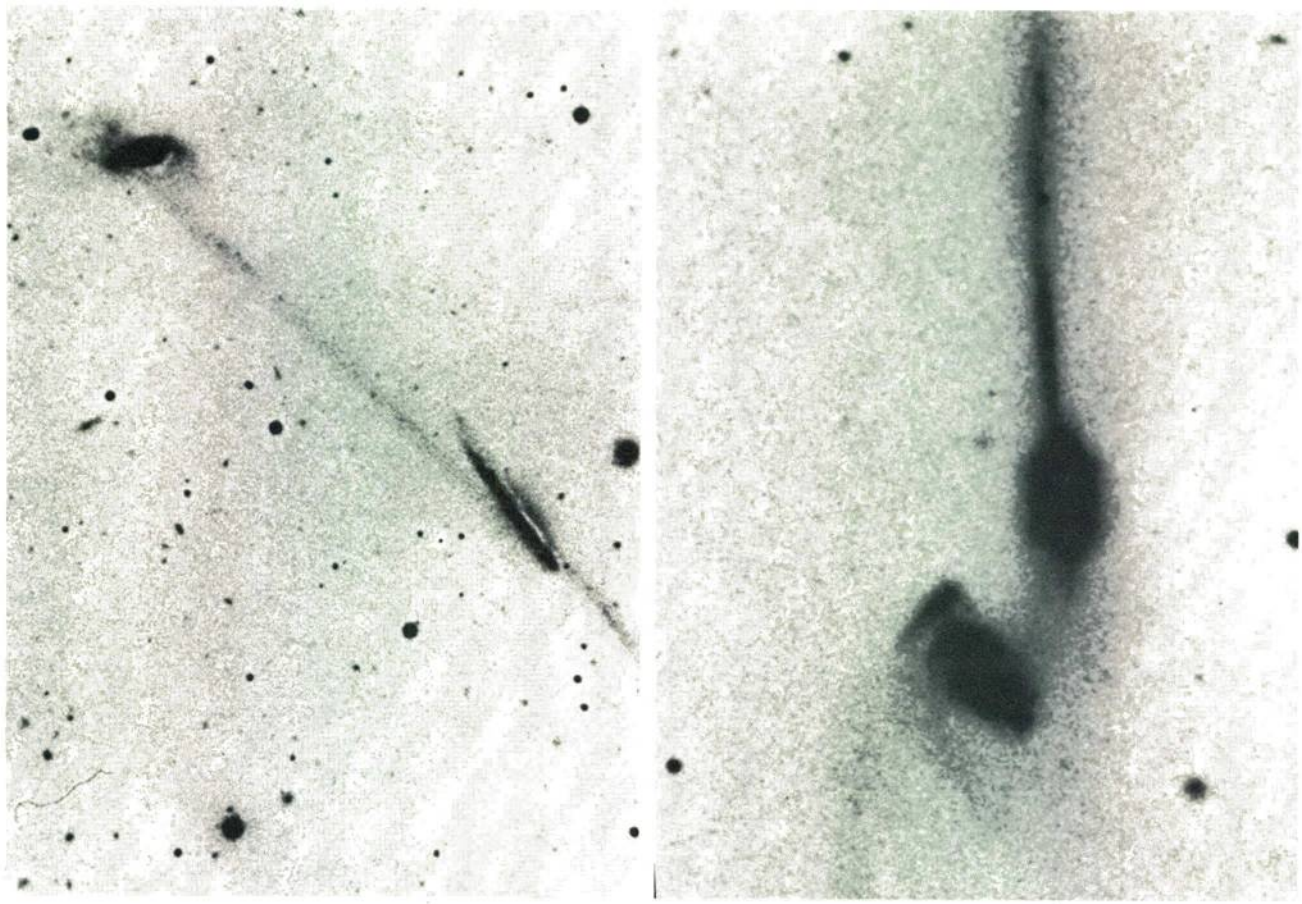
But the real surprise was something else. Although the Toomre brothers started with two uniform disks which bent up at the edges during the time of closest approach, the points representing stars in the galaxies started to form a spiral pattern. The Toomres seem to have stumbled onto a possible cause for spiral patterns in many galaxies. They went on to model the situation of M-51 and its companion and found that the outer spiral structure seen in M-51 was probably produced by the interaction with NGC-5195.

We know that our sun is located in a galaxy that also has a spiral pattern, although it is difficult to form an accurate picture of what that pattern is, since we are unfortunately situated inside it. Theoretical astrophysicists recently proved that spiral structure could indeed be maintained for many galactic rotations. However, they could not explain the origin of spiral patterns. Now the Toomres appear to have shown that at least outer spiral structure might be the direct result of close interactions between galaxies in groups or clusters.

After the effect of the interaction with the Magellanic clouds has worn off, it is quite possi-


Edge On View of The Milky Way Galaxy.
600 light-years
Center of Milky Way Galaxy
10,000 light-years
60 to 100,000 (?) light-years
To Magellanic Clouds

The Milky Way galaxy is not shaped like a flat disk with a bulge at the center. This traditional view has been changed so that astronomers now believe our galaxy is shaped like a hat brim — one edge bends up, the other down.



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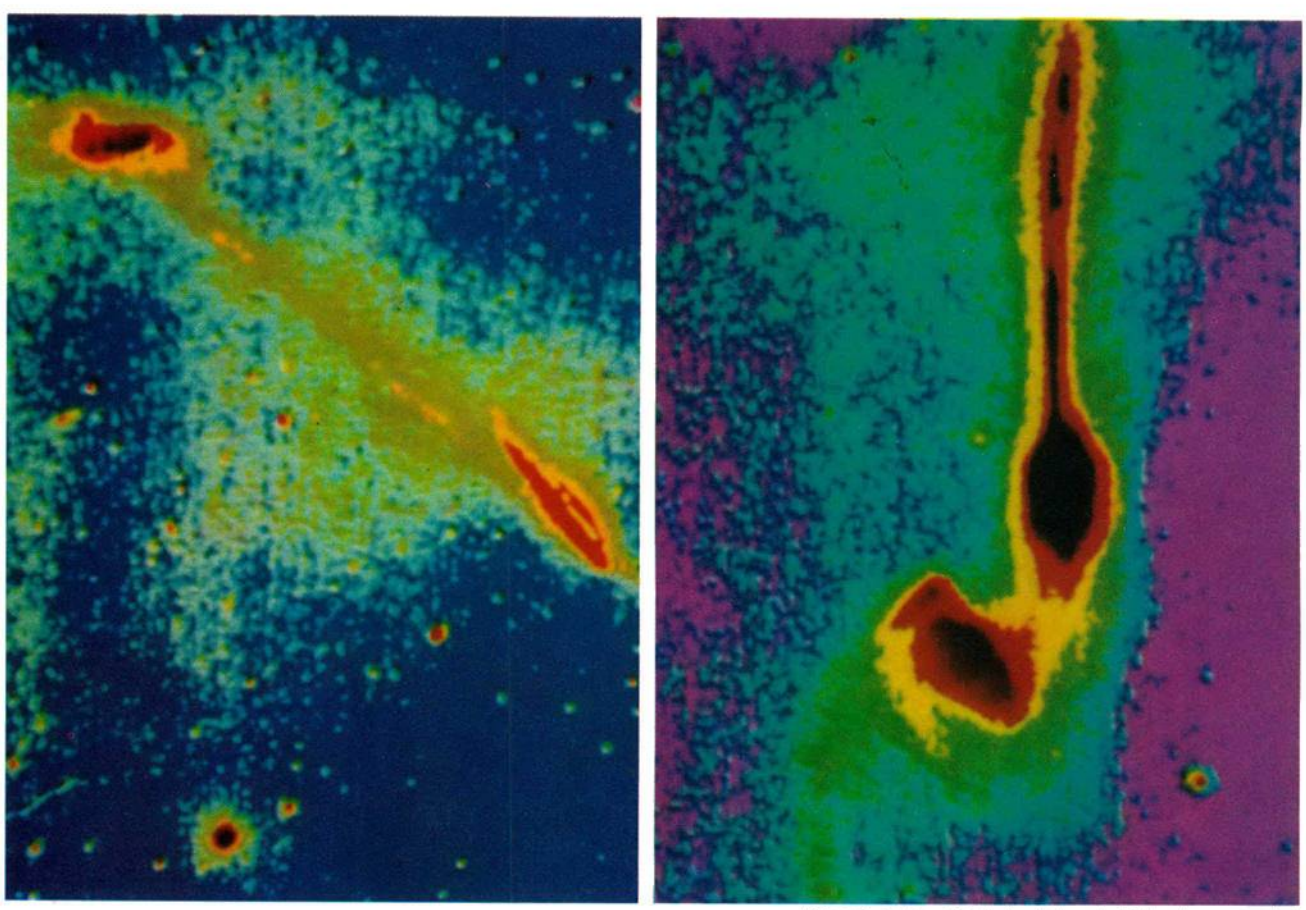

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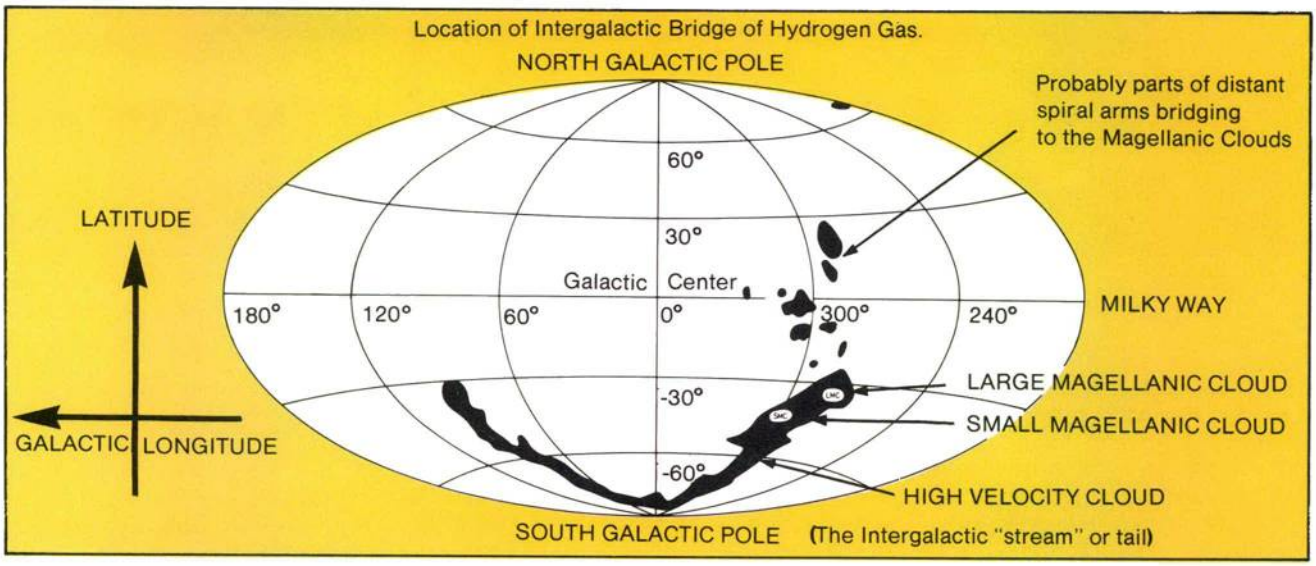

ble that our galaxy will lose its spiral pattern. Stars and gas will slowly collapse inward and form an amorphous disk shaped object until the next time the clouds come by to generate spiral structure all over again. In addition, if the clouds had been in a direct orbit, they would have caused so much disruption of the Milky Way system that our galaxy would appear totally different from the way it appears now. There are other galaxies which probably interacted destructively in this way, explaining some of the quite remarkable structures one sees in photographs of extra-galactic nebulae.

If the Magellanic clouds have passed by our galaxy in the way we now think, then it is probably that they also dragged out matter from the outskirts of our galaxy and vice versa. But where is the subsequent intergalactic bridge that might be expected? Any good theory ought to predict where the bridge should be. This bridge would be invisible since it probably contains mainly neutral hydrogen gas. However, radio astronomers studying radiation from this gas should be able to find it. Searches were made in areas where the Toomres predicted the intergalactic bridge might be, but nothing was found.

The story does not end there however. A possible bridge of matter joining our galaxy to the Magellanic clouds may have been found — a very definite "tail" or stream of matter radiating from the clouds has been found. First a little about the newly discovered stream in the context of how it was discovered.

One of the most enigmatic problems that confronted radio astronomers for a decade was the existence of hydrogen gas moving at large velocities well above and below the Milky Way. We expected only to find slow moving, nearby hydrogen in these directions since the galaxy is supposed to be a flat disk. However if our galaxy is distorted, then the hydrogen in distant spiral arms would appear well away from the Milky Way band and this matter would appear to have high velocities toward or away from us due to the rotation of the galaxy.

One high velocity cloud was found near the south galactic pole — a direction in which distant spiral arms were hardly likely to exist. The South Pole cloud, as far as northern hemisphere observers could ascertain, was about 70 degrees long and the velocity of the hydrogen in the cloud ranged from near zero with respect to us to a velocity along its length of about 400 kilometers per second toward us.

Recently, Don Mathewson found that the cloud reached all the way to the Magellanic clouds themselves, where radio emission blended with emission from the Magellanic clouds. The two Magellanic clouds were already known to be linked by their own bridge of hydrogen gas. Mathewson refers to the South Pole cloud as a stream of matter. It would appear to originate at the clouds and track off into space if the motions in the stream are interpreted correctly. The patches of clouds seen near and above the Milky Way at longitude 300 degrees may be part of a bridge which is the outer spiral arm of our galaxy reaching to the Magellanic clouds. The stream, however, is very similar to the structure seen in the illustrations on page 44 .

No doubt during the next year, astronomers will develop a clearer picture of how the Magellanic clouds must be moving in order to explain the precise nature of the newly discovered stream (tail) and the probable bridge. They should also be able to draw a better picture of what our galaxy really looks like in its outermost, distorted regions.

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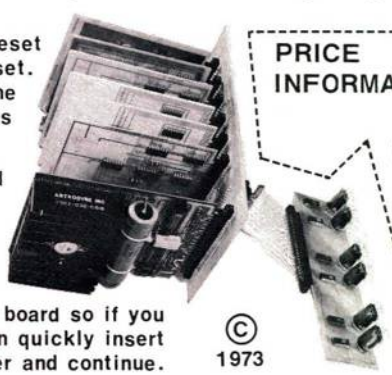

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ASTRO-NEWS

Latest News From the World of Astronomy

Comet Kohoutek Disappoints Early Viewers

Comet Kohoutek has now been seen in the morning sky for about a month by amateur astronomers using small telescopes and binoculars. Throughout this period it has remained below its predicted magnitudes and at the end of November was about half a magnitude below the most pessimistic estimate provided by professional astronomers. It is nearly three magnitudes below the more optimistic estimates that were pronounced a few months after the comet's discovery in March 1973.

Kitt Peak National Observatory Photograph

The above photograph of Comet Kohoutek was taken in the early morning sky of Nov. 29 with the 12 inch Schmidt telescope at Kitt Peak National Observatories. This 10 minute exposure was made by Dr. Michael Belton of the Observatories' scientific staff. The tenuous tail extended 3.8 degrees — or approximately 7,000, 000 miles — from the head of the comet when this photograph was made. The comet's magnitude was approximately +6.

Since the fainter estimates now appear to be the ones the comet will follow, this means a minor adjustment is necessary in the listings in the October issue of ASTRONOMY. During the prime period for observation, early this month the comet will not likely exceed magnitude -1. (This will probably be in the first week in January.) By midmonth when it is higher in the sky, Kohoutek will be about magnitude +1. These magnitudes refer to overall brightness of the comet. Its central coma will be two to three magnitudes fainter than this.

But the comet will definitely be a naked eye object and probably will still be the most spectacular comet since Halley's in 1910. However it will not rival the brilliant comets of the 19th century, half a dozen of which were far more spectacular than Halley's comet and were seen in broad daylight.

Predicting a comet's brightness is a tricky business. Comets have been known to suddenly increase in brightness 10 thousand times. Obscure comets have, on occasion, flared into brilliance. Conversely comets predicted to do great things have fizzled into obscurity. During the prime period for convenient observation from Jan. 8 to 18, the tail of Comet Kohoutek should not exceed about 10 degrees in length, differing markedly from the 30 to 40 degrees predictions made earlier. The optimistic predictions are in no way a reflection of the competence of professional astronomers. Indeed this illustrates the need for further study of comets for a more exact understanding of their nature.

Mariner 10 Speeds to Venus and Mercury

After some tense moments Mariner 10 — the first spacecraft to fly by two planets — is now on course to pass 3,600 miles above the clouds of Venus.

Shortly after blastoff last Nov. 4, the 1160 lb. spacecraft's two cameras were found to be far cooler than expected. A tiny heater had failed to operate thus jeopardizing the most exciting part of the $100 million mission. Officials at NASA's Jet Propulsion Laboratory had to decide whether to use a backup spacecraft on standby at the Kennedy Space Center.

As a test the cameras were turned back toward Earth and the moon. The results were excellent. Despite the fact that they were operating at 50 degrees below the predicted operating range, all seemed to be normal.

So for the moment, the crisis was averted. The cameras have been stowed to partially protect them from their frigid surroundings. Mariner 10 is now swinging sunward and is warming daily. The backup spacecraft has been taken from its Atlas Centaur rocket — the launch "window" has passed so if anything happens to Mariner 10 now, it's too late for help.

When the craft passes Venus on Feb. 5 it is scheduled to take up to 5,000 pictures of that cloud-cloaked world. The photos will be the first spacecraft photos of that planet. Scientists are hoping the pictures will show a hole in the clouds or perhaps some kind of cloud structure that may shed light on their nature.

The gravity of Venus will fling Mariner 10, at increased speed, closer to the sun toward its next objective — Mercury. All this interplanetary navigation requires precise aiming achieved through maneuvering jets on the spacecraft itself. The success of this first two-planet mission depends on many factors; but for now, all is well.

Kohoutek Spurs Study of Space Craft to Comets

Although some thought was given to preparing a spacecraft that would make a near flyby of Comet Kohoutek, the idea was abandoned because of lack of development time. However the appearance of Kohoutek has increased interest in having a closeup look at the nucleus of a comet — the tiny core from which the great streaming tail of dust and gas emerges as a comet approaches the sun.

Comet Kohoutek is suspected to have a nucleus approximately 15 miles in diameter — a giant among comets. But even at its size it is impossible to see or learn much from Earth's distance. A flyby spacecraft approaching within 500 miles of the nucleus could photograph and analyze it with onboard instruments revealing information that would seem unlikely to be obtained otherwise.

Mission planners at NASA have been studying the possibility of flying such a spacecraft and have examined 20 close approaches of known comets during the next quarter century. They were looking for comets with orbits that carry them fairly close to Earth. The candidate comet should have a history of Earth-based observations which would provide a foundation of basic knowledge to which spacecraft observations could be added. A comet with an orbit inclined only slightly to the plane of the solar system was desired because large expenditures of fuel are required to send a space vehicle out of the plane of the solar system to intercept a comet.

So the comet suitable for a flyby mission must be periodic (have an orbit that brings it near Earth and the sun at intervals of a few years) and have a low inclination orbit. The comet that meets these criteria most closely is Comet Encke which has a 3.3 year orbit and ranging from 32 to 381 million miles from the sun. It has been observed on most of its returns since its discovery by Mechain in 1786. Johann Franz Encke, like Halley, did the orbital calculations that proved the comet to be periodic.

There is one drawback with Comet Encke — almost no dust has been observed in its tail in recent years (see Gazer's Gazette last month). This implies it has passed through perihelion (its nearest point to the sun) many times and has had its dust component removed by repeated heating. The tail is now almost entirely gaseous and visually unspectacular making Encke rather atypical in this one respect. However this very circumstance may permit a clearer view of Encke's estimated one mile wide nucleus when the spacecraft's cameras begin closeup photography.

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Misty the Cat Hit by Meteorite Debris

On Nov. 8 a chunk of rock, presumably from the asteroid belt, smashed through the roof of a Denver garage and shattered on impact with the concrete floor of the structure.

A tenant of the garage, a calico cat named Misty, was sitting behind a pile of old furniture and was slightly scarred by flying pieces of rock as the meteorite gouged a two inch gash in the concrete floor of the garage.

Glen Huss, director of the American Meteorite Laboratory, reported 57 fragments of the impact were sent to the Museum of Natural History in Chicago for analysis. Huss said the object was the most highly crystallized meteorite he'd ever seen. He added that it was composed primarily of magnesium, olivine, iron pure pyroxene and crystallized troilite.

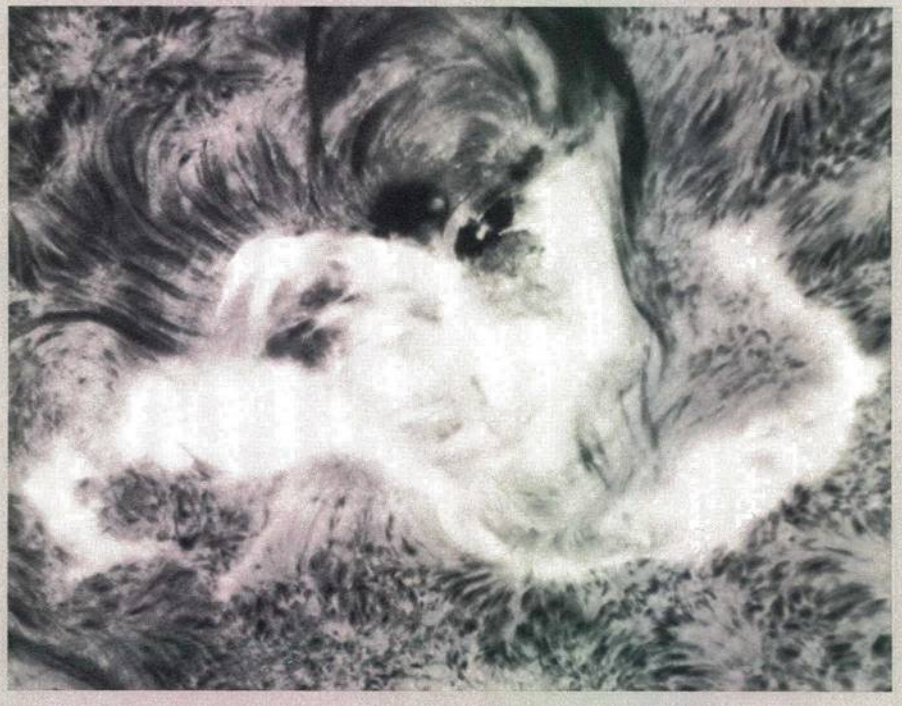
A meteorite hitting a structure near or on inhabited parts of Earth is extremely rare — only two or three of these kinds of falls are recorded each decade. Only once has a human ever been known to have been hit by a meteorite fragment. It was a similar circumstance of one plunging through the roof of a structure. However, as in this case, the injuries were minor. Most meteorites sufficient in size to cause a noticeable impact on Earth are believed to be fragments from the asteroid belt and not remnants of comets as normal "shooting stars" or common meteors are believed to be.

Solar Outburst May Slow Earths Rotation

One of the most violent eruptions in recent years tore billions of tons of material from our star in August, 1972. The turmoil on the sun was detected from Earth in the form of a massive group of sunspots and associated magnetic disturbances. Interruptions in communications on our planet and an increase in auroral activity was all part of the solar violence.

The high energy particles released into space by such an explosion are trapped in the magnetic field of Earth and should have various influences on our planet. A decade ago, French astronomer A. Danjon suggested that major solar disturbances could affect Earth's rotation by slightly varying the length of the day. It is known that the day is lengthening by about 1/1000 of a second per century but this is due almost entirely to tidal friction. Until the storm of 1972 there was no confirmation of Danjon's suggestion.

Now two astronomers have used data from the United States Naval Observatory to determine that five days after the storm a small abrupt increase in the length of the day occurred. Dr. John Gribbin and Dr. Stephen Plagemann called this lengthening a glitch, however it amounted to only billionths of a second and was discovered by comparing Universal Time with Atomic Time as recorded at numerous observatories around the world. The two scientists suggest a connection between the solar storm's effects on Earth's atmosphere and rotation. The results have yet to be confirmed but the existence of effects of major solar disturbances on our planet seems to be well established.



California Institute of Technology Photograph

A giant arching loop of solar material exceeding the mass of earth was lifted from the sun on Aug. 7, 1972, during one of the largest solar flares ever recorded. It can be seen as a dark inverted (U) at top center of this detailed photo of a 100,000 mile wide zone of the sun. If this tongue of solar material had been observed near the limb of our star it would have appeared as a spectacular solar prominence. Intense magnetic fields produced the activity seen here. Hot material is lighter in this photo taken in the light of hydrogen alpha (the result of filtering that allows observation of more detail than can be seen in normal light). A specially designed telescope at Big Bear Solar Observatory in California captured this spectacular view.

Astronauts blood change still puzzling.

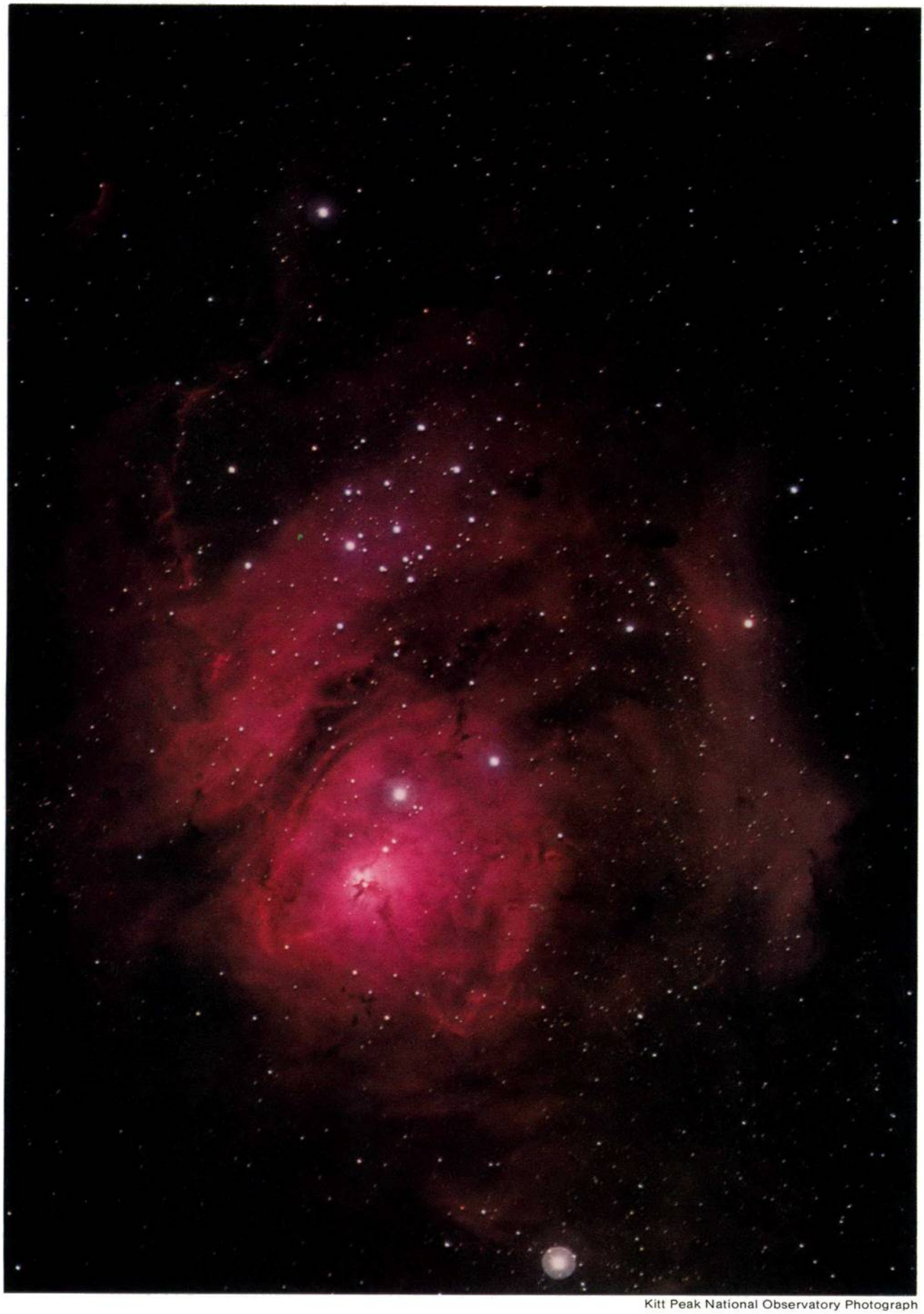
During the entire manned space program a mysterious decline in red blood cells has occurred during each space mission. The longer the astronauts stayed in space the more they seem to lose.

At first it was believed that the pure oxygen breathed by the Gemini and Apollo astronauts was responsible. But Skylab had an airlike atmosphere and its crews have shown a loss in red cells too — the first Skylab crew suffering a 15 percent loss and the second a 12 percent loss. In addition the first crew lost about 10 percent of their blood plasma and the second crew declined 13 percent. This meant that the pure oxygen atmosphere was not the culprit, again throwing open the question for further investigation.

There was no sign that the red cells had been destroyed thus eliminating the possibility of radiation as a cause. By the process of elimination National Aeronautics and Space Administration medical experts pointed the finger at weightlessness. They reasoned that under weightless conditions the body would require less blood because it wouldn't be working as hard and therefore the bone marrow, where the red cells are produced, would slow down on production. In addition it has been noted that during space flight the heart shrinks a little and grows sluggish, mainly because it doesn't have to pump blood against gravity.

"The heartbeat goes down, the food intake goes down and the metabolic rate appears to go down. The result is you have no real demand for red cells and so you don't make them anymore," said astronaut-physician Dr. Joseph Kerwin, who was one of the three crew members on the first Skylab flight.

The first two Skylab crews have regained their normal blood counts, but they recovered at different rates. In fact the individual characteristics of loss and subsequent regaining of blood varies from one astronaut to another. So the entire question of blood loss on space missions is shrouded in mystery. NASA doctors are waiting with keen interest to see what effect the proposed 84 day mission will have on the Skylab 3 astronauts now in orbit around Earth. A solution, or at least an understanding of this blood enigma, is necessary before longer interplanetary space ventures are even contemplated.



Kitt Peak National Observatory Photograph

New Portraits of the Universe

Much of the beauty of the universe is concealed from our view by the vast distances that separate us from the celestial spectaculars shown on these pages. To the unaided eye nothing of the grandeur and color of gigantic nebulae can be seen. Similarly the multiple arms of a spiral galaxy are beyond the capabilities of unaided human vision.

Even when a large aperture telescope is used, the human eye is still not capable of detecting the faint details and subtle colors of deep sky objects. The colors in the Trifid nebula, for example, are completely beyond the perception of the most acute observer at the eyepiece of the world's largest telescopes.

Modern photographic films have the ability to accumulate the impinging light from a faint celestial object. The image builds up on the film unlike the fleeting image registered by the human eye. So the film, like a rainbarrel, collects and retains the light received by the giant "eye" of the telescope.

Most astronomical photographs are taken with black and white film because of its greater sensitivity — fainter objects can be recorded in shorter time. Because of the permanency and accuracy of film, few astronomers spend any time looking through a telescope. Instead he photographs his celestial prey and examines the results at his leisure back at the laboratory.

Almost as a by-product of this research the incredible beauty of the universe is revealed in its infinite variety — star clusters like glittering jewel boxes, nebulae resembling multicolored cumulus clouds of a lazy summer day, and mighty galaxies with their throngs of stellar inhabitants wrapped into spirals around a glowing nucleus. All these wonders can be frozen in time on a photographic plate.

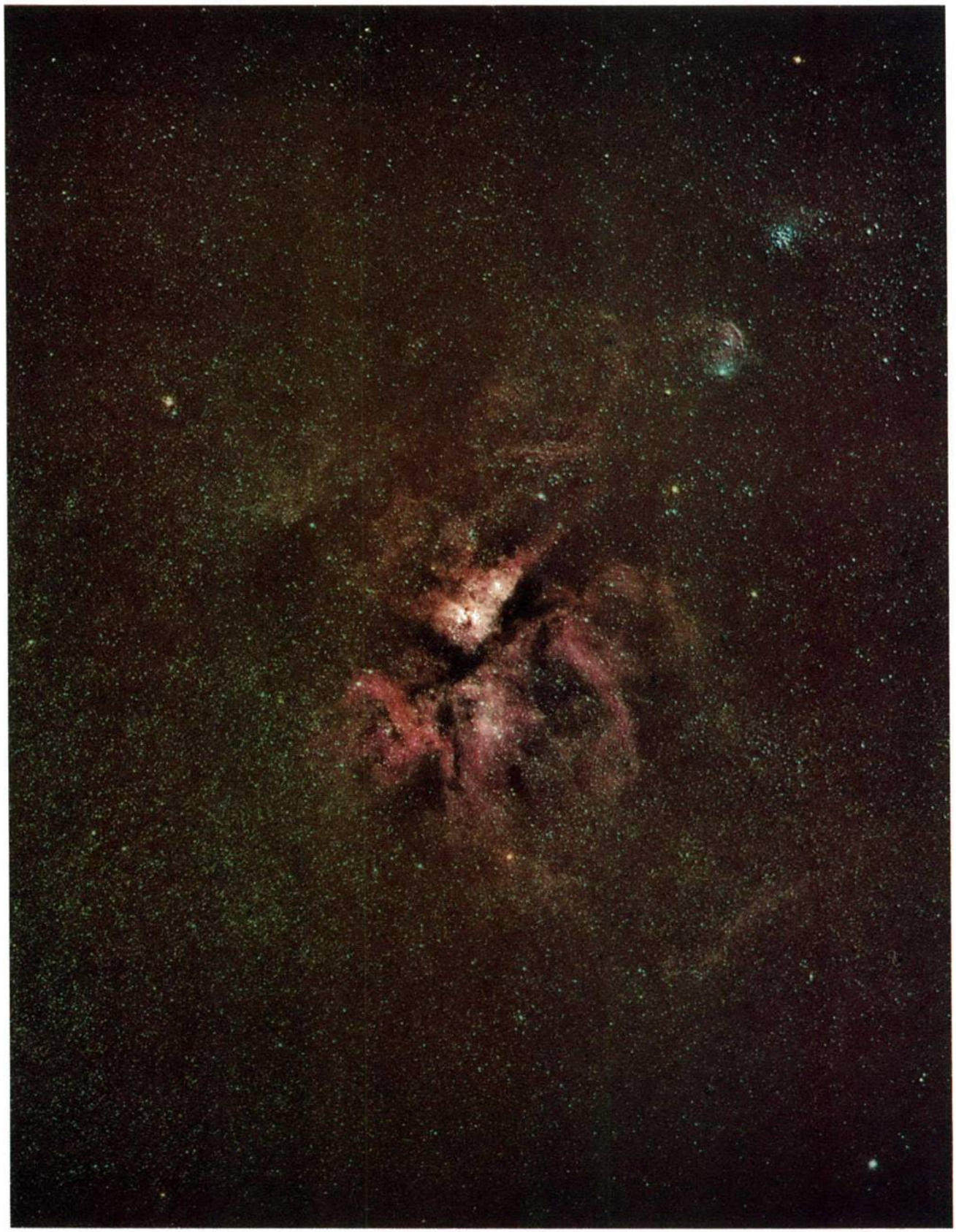
Color photography is rarely used at major observatories because virtually the same scientific information can be obtained by using more sensitive black and white emulsions of varying spectral sensitivity. The primary virtue of color portraits of deep sky objects is that they are the most accurate representations we have of what these objects really look like. There are ways of calibrating the film so that the final results can be considered to be "true". Although of limited use today, color photos of deep sky objects may soon be used by astronomers to pinpoint areas of interest so that they can be examined in detail by other methods.

The film used for the color photos on these pages was Kodak Ektacolor Type L. The original plates were 8 by 10 inches in size. They were all exposed for about one hour at the prime focus of the new 158 inch Mayall telescope at Kitt Peak National Observatory near Tucson, Ariz. This telescope — the second largest in the world — is a powerful new tool that incorporates the

The Lagoon nebula is a giant cloud of gas and dust in the constellation Sagittarius. Like the Great Nebula of Orion, it is classified as an emission nebula. At this gas cloud's center are new stars in the process of formation. While spectacularly revealed here in color, in future millennia our descendants will not see a red glowing cloud, but a cluster of blue, hot, youthful stars. Photographs in color help show basic processes going on in celestial objects. Red in gas clouds generally reveals emission or radiation. Blue reveals reflection — as sunlight scattering in Earth's atmosphere to make the sky look blue.

The Sombrero galaxy (NGC-4594) is a spiral "island universe" like our own Milky Way. Containing more than 100 billion stars, this galaxy is some 30 million light-years from Earth. Hundreds of globular clusters form a halo about this massive galaxy giving its outline a soft blur. The dark band through its center is caused by obscuring dust clouds at the galaxy's rim.

Kitt Peak National Observatory Photograph

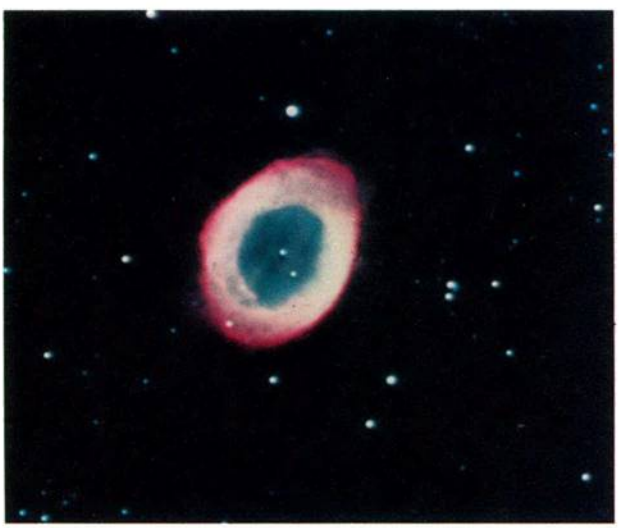


Kitt Peak National Observatory Photograph

One of the richest regions of the Milky Way galaxy is highlighted by the Eta Carinae nebula, a great diffuse nebula 8,700 light-years distant. This cloud of hydrogen gas is similar to, but larger than, the Orion nebula. In its midst are dozens of hot blue stars recently born and flooding the surrounding sky with energy, illuminating the nebula in the process. Unfortunately this spectacular celestial cloud is only visible from the southern hemisphere. This photo was taken with a 24 inch Schmidt telescope located at Cerro Tololo in Chile.

Kitt Peak National Observatory Photograph

The Trifid nebula is a birthplace of stars where hundreds of new suns will ignite during the next few million years. The Trifid is about the same size as the Orion nebula (see last month's ASTRONOMY) although at 3,000 light-years it is twice as far away. The red regions are being stimulated by the radiation from several hot stars in the nebula's core.



Kitt Peak National Observatory Photograph

Invisible to the naked eye, the Ring nebula looks like a ghostly smoke ring in small telescopes. Here the 158 inch Kitt Peak reflector gathers enough light to show fine details not seen visually. The nebula is actually a sphere of gas about one light-year across and 5,000 light-years distant. At its center is one of the hottest stars known. Its temperature of 100,000 degrees makes the gas fluoresce colorfully. The nebula was created when — for some reason not fully understood — the hot star puffed off its outer layers.

latest scientific advances for astronomical research. It also allows the inhabitants of planet Earth to glimpse the beauty of the universe — a beauty that we have only begun to see.

The photographs accompanying this article (except for the Eta Carina photograph), are the first color photographs made with the new Kitt Peak telescope. Included in this series is the photograph of M-16 on page 17 of this issue which helps illustrate Dr. Whipple's article "The Birth and Death of a Comet". These photographs have never been published before, and we at ASTRONOMY are honored at the privilege of allowing you to see them first in our magazine.

Since these are only the first color photographs — and Kitt Peak's first attempt at color astrophotography with the new Mayall telescope — observatory scientists say they are not the best quality that can be produced with the telescope. Future modifications in technique and special processes should greatly improve the quality of Kitt Peak National Observatories photography.

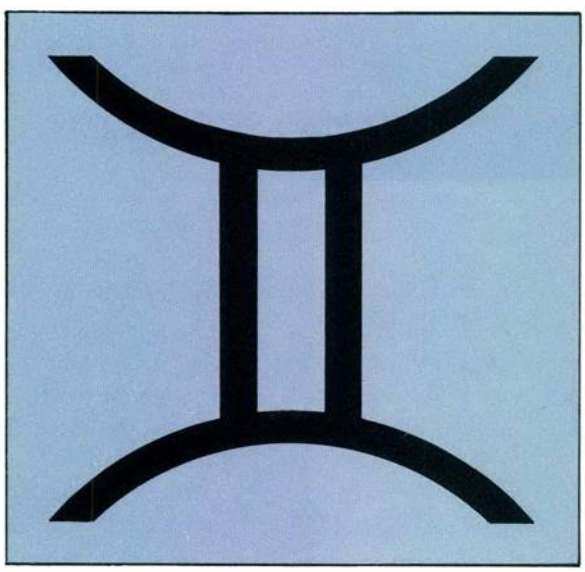
In the meantime, enjoy these new portraits of the universe.

CONSTELLATION CLOSE-UP

GEMINI

by

Thomas C. Bretl



The striking winter group of stars, Gemini the Twins, is most appropriately named. Third constellation of the zodiac, Gemini is highlighted by the prominent fraternal pair, Castor and Pollux. It not only forms a pattern suggesting two stick figures walking arm in arm, but also contains an amazing number of closer double, or "twin", stars. No fewer than a dozen of its major members (fourth magnitude or brighter) are binaries of some kind, and most of these are very suitable objects for small telescopes.

Heading the list of Geminid binaries is Castor, considered by some observers to be the finest double star visible from northern latitudes. Castor is an excellent reminder that bin-

aries are dynamic systems where stars' mutual gravitational attraction locks them in a celestial tug of war, causing continual acceleration and positional change. In Castor's case this is illustrated by the rapidly changing separation of the components, and complicated by the fact that at least four other stars are also part of the same system!

As Castor's two brightest components (magnitude 2.0 and 2.9) revolve around each other through a period of 350 years, their separation varies considerably, from a maximum 6.5 seconds of arc (in 1880) to less than the present separation of 2.2 seconds of arc. At the same time a third, tenth magnitude star, now 70 seconds of arc from the much brighter pair, interacts with both of them. All three stars are close, spectroscopic binaries!

Castor and other double stars in Gemini are listed this month in the order of increasing difficulty of resolution. With their wide variety of magnitudes and separations, the great number of doubles in this constellation affords a good opportunity to test the resolving power of your telescope. This ranking, of course, is only approximate, and it must be remembered that splitting close double stars is a test of the atmosphere and your own eyesight as much as it is a test of the quality of your telescope.

Stars in Gemini occur in clusters as well as in pairs, and M-35 is among the most beautiful to be found anywhere. It is rich, containing over 120 stars within its 40 minute of arc diameter, and is bright enough to be seen with the naked eye. Located near Eta Geminorum, in the western "foot" of the constellation, it has been

TABLE OF OBJECTS IN GEMINI

Double Stars

Star	Magnitudes	Sep.	Colors	R.A.	Dec.
20	6.0 - 6.9	20.0"	Yellow-blue	06^h31^m	$+17°47'$
υ	4.2 - 8.0	113 "	Blue-white-yellow	06^h27^m	$+20°14'$
ϵ	3.0 - 9.5	111 "	White-blue	06^h42^m	$+25°11'$
38	5.4 - 7.7	6.7"	Yellow-blue	06^h53^m	$+13°13'$
κ	4.0 - 8.5	6.8"	Orange-blue	07^h43^m	$+24°28'$
ς	3.2 - 8.2	6.7"	Orange-blue	07^h18^m	$+22°03'$
α	2.0 - 2.9	2.2"	Green-white (both)	07^h33^m	$+31°57'$
λ	3.7 - 10.0	10.0"	Green-blue	07^h16^m	$+16°36'$
μ	3.0 - 11	73 "	Yellow-blue	06^h21^m	$+22°31'$
τ	5.0 - 11.5	1.9"		07^h09^m	$+30°18'$
ρ	4.2 - 12.5	2.8"		07^h27^m	$+31°51'$

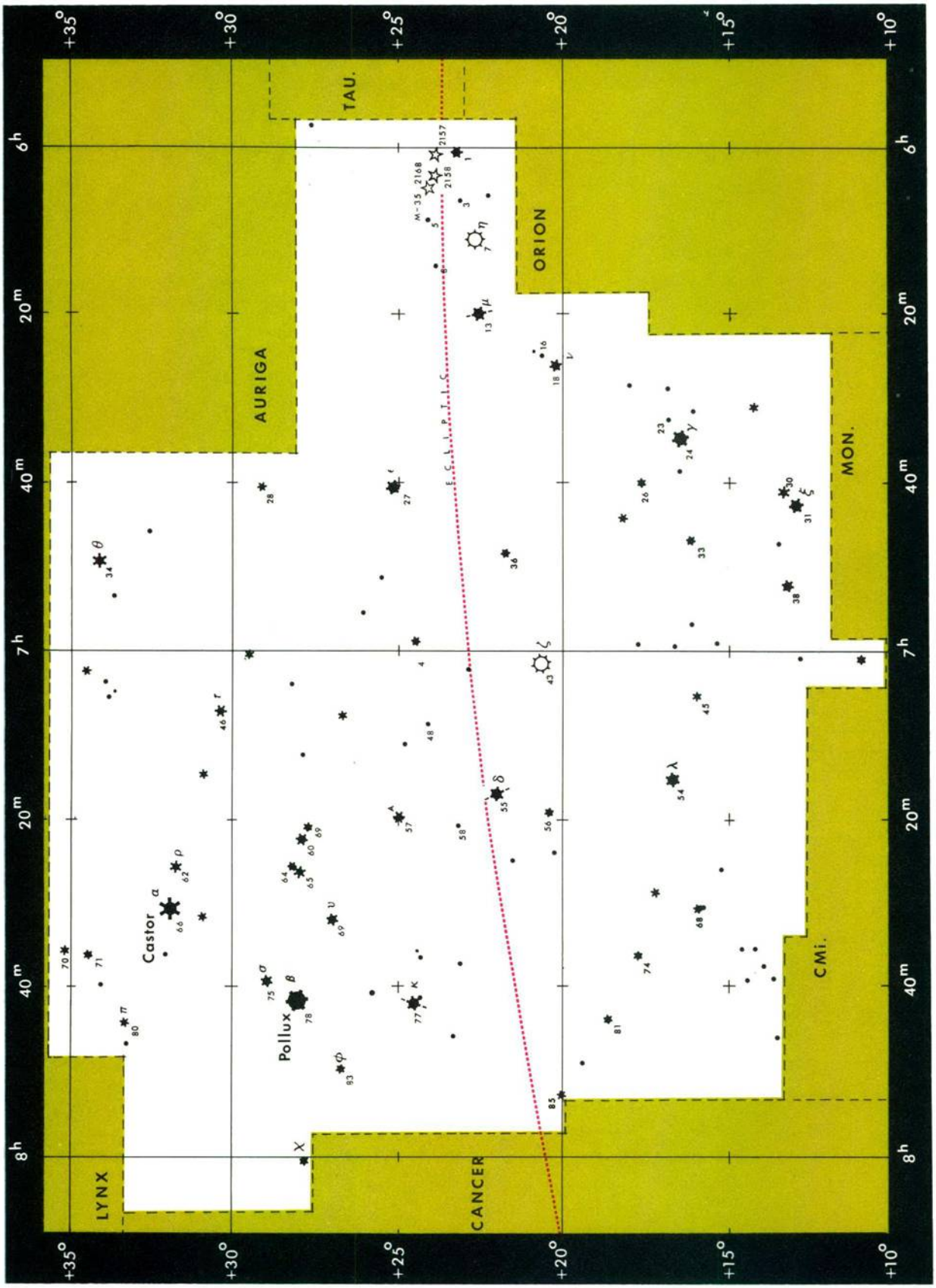
Variable Stars

Star	Max. Mag.	Min. Mag.	Period	R.A.	Dec.
η	3.1	3.9	233 days	06^h13^m	$+22°31'$
R	5.9	14.1	370 days	07^h05^m	$+22°46'$
ψ	8.9	14	Approx. 86 days	07^h53^m	$+22°05'$

Clusters and Nebulae

NGC	Type	Mag.	Size	R.A.	Dec.
2168 (M-35)	Open Cluster	6	40'	06^h07^m	$+24°20'$
2392 (HIV-45)	Planetary Nebula	9	.8' x .7'	07^h27^m	$+20°58'$

EPOCH 1970



Map by Raymond G. Coutchie

Stellar Magnitudes -1 0 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 & fainter

Diffuse Nebula Double Stars Variable Stars

Galaxies Planetary Nebula Open Star Clusters Globular Clusters

described as a "marvelously striking object ... full of brilliant stars, unusually equal in magnitude" and "an excellent object for any telescope".

One half degree to the southwest, just beyond the edge of M-35, lies another open cluster of a much different nature, NGC-2158. Designated as HVI-17 by Herschel, this is a very compressed, rich cluster of dim stars that would probably be overlooked and neglected were it not for its close proximity to M-35. In a six inch richest field telescope it appears as a small cloud, in striking contrast to its brilliant neighbor, and adds an air of subtlety to an already very fine field.

No description of this area's attractions could be complete this year without mention of the planet Saturn. Always a favorite in telescopes of any size, Saturn is spending this winter near M-35, at times very close to Eta Geminorum. Its high position in the sky, together with the openness of its rings, make this winter one of the best times to observe this beautiful planet.

Other objects of interest this month include NGC-2392, two degrees west and one degree south of Delta Geminorum. This small planetary nebula is in the same general class of oval planetaries as the better-known Owl nebula, but in small telescopes will appear only as a ninth magnitude "fuzzy star". It has been compared in appearance to a telescopic comet, and considered quite remarkable by such famous observers as Sir William Herschel and the Earl of Rosse. A tenth or eleventh magnitude star lies near its center, and seen through large telescopes various dark spots or bright rings have been reported.

Variable star observers will find several interesting, and at times very unpredictable, examples listed in this month's table of objects. The most unusual of these is U Geminorum. Together with SS Cygni, U heads a class of rare variables that at irregular intervals suddenly burst into prominence, increase several magnitudes in brightness, and then just as quickly fade back to normal again, remaining inconspicuously quiet for an unpredictable length of time. U, for example, has been known to change as much as three magnitudes with a 24 hour period.

Irregular variables such as U and SS may be a kind of recurring novae. Interestingly, it has been observed that the greater the time between outbursts in these variables (and in longer period recurrent novae), the greater the outbursts have been. Perhaps some of the most spectacular novae of the past will, someday, flare up brilliantly once again!

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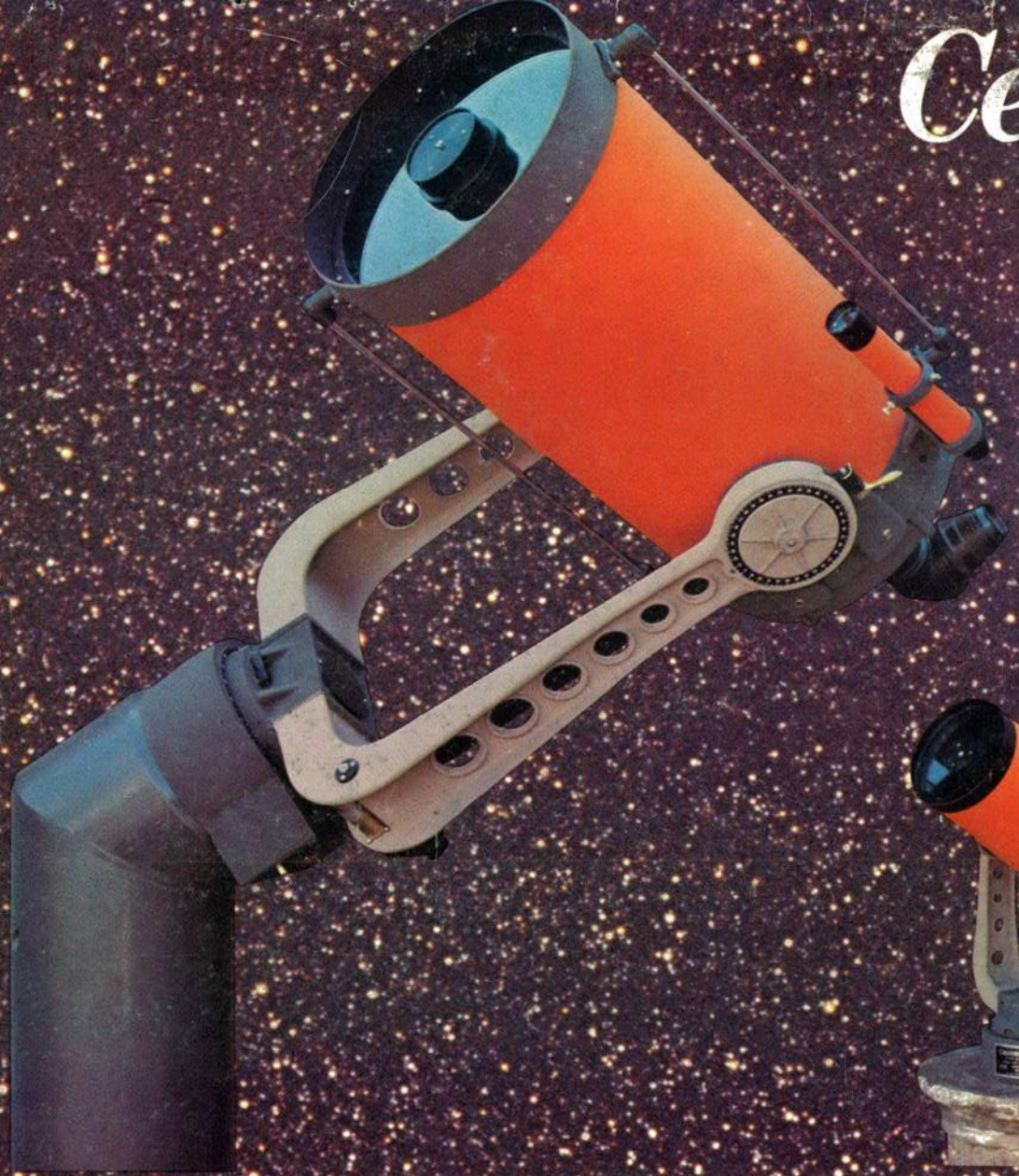

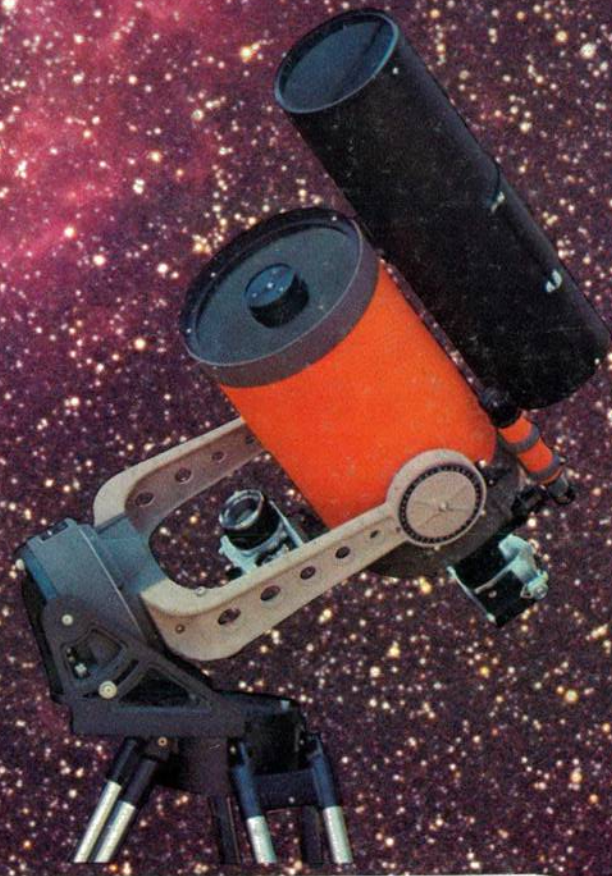

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